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# RESEARCH

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# Cumulative Auditory Fatigue

James F. Jerger

Auditory fatigue refers, in general, to the ear's loss in sensitivity following acoustic stimulation. Although interest in the measurement of fatigue has increased markedly in recent years, comparatively little attention has been given to a closely related problem, the possible cumulative effects on sensitivity produced by successive acoustic stimuli.

Lightfoot and Jerger (7) were among the first to investigate this phenomenon in detail. Working in an area that has been called 'short-duration auditory fatigue,' they explored the cumulative effect of a two-second burst of thermal noise on the threshold shift for 35 msec, 4000 cps tone pips over the course of 100 successive noise bursts. With burst SPLs of 90, 100, and 110 db, burst rates of three and six per minute and burst-pip intervals ranging from 90 to 1000 msec, a systematic increase in the threshold shift was observed. It was also noted that the degree of increase, or cumulation, showed wide variation among different subjects.

Harris (*1*) subsequently observed a similar phenomenon while measuring the threshold shift at 1000 cps following one minute of stimulation by a 750 cps tone at an SPL of 120 db. After the subject's threshold had recovered to pre-exposure level following stimulation, the one-minute fatiguing tone was immediately reintroduced. Examination of the threshold recovery curve following this second exposure revealed a prolongation of recovery indicating that the effects produced by the first fatiguing tone had not fully dissipated at the onset of the second fatiguing tone although the threshold sensitivity had shown complete recovery. Harris (*1*) suggested the term 'latent damage' to explain the prolongation of the second recovery curve and advanced the following hypothesis:

> An initial stimulation . . . has the effect of temporarily damaging for a few hours the more susceptible cells, whose prolonged recovery process yields the sharply decelerated recovery curves commonly found in temporary threshold shift studies. But complete audiometric recovery can occur in a few minutes, before all effects are dissipated because, through multiple innervation, other cells can function to produce the most acute psychophysical threshold. However, upon a quickly-following second stimulation the next most sensitive cells, perhaps already bruised to some extent by the first stimulation, are rendered insensitive for a time, and in such quantities that the threshold finally does shift, beyond that seen after a single stimulation.

Harris then observed that if the second fatiguing stimulus were presented

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before recovery from the first was complete, even more cumulation was observed. Finally, marked individual differences in the cumulative effect were noted.

In summary, then, the limited observations that have already been made indicate the existence of cumulative fatigue as a real phenomenon characterized by marked individual differences. The purpose of the present study was to explore this cumulative fatigue phenomenon in greater detail.

Although the measurement of cumulative fatigue is an inherently time-consuming task, a considerable body of data was obtained by taking advantage of the CAFT (chrono-audio-fatigue-test) procedure (*4*), a method which permits the relatively rapid measurement of recovery following intense stimulation. Within the framework of this testing procedure a study was designed to evaluate the following problems: 1. What is the relationship between cumulative fatigue and the intensity of the fatiguing stimulus? Specifically, does the degree of cumulation increase gradually as intensity is raised, or does it suddenly appear at some critical intensity level? 2. To what extent are the cumulative effects observed at different fatiguing intensities correlated? 3. How is the intersubject variability in cumulative fatigue affected by the intensity level of the fatiguing stimulus, and how does it compare with the variability of recovery after the first fatiguing stimulus? 4. To what extent is the cumulative effect related to initial, or pre-fatigue, threshold sensitivity? In an effort to evaluate these questions, the cumulative effects induced by three successive one-minute fatiguing stimuli were measured as a function of the intensity level of the fatiguing stimulus.

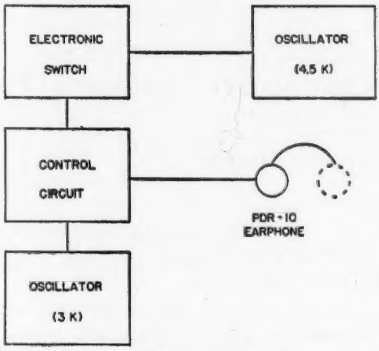


FIGURE 1. Simplified block diagram of CAFT (chrono-audio-fatigue-test) apparatus used to measure recovery time.

## Procedure

Figure 1 shows a simplified block diagram of the CAFT apparatus used to obtain the fatigue measures. A detailed explanation of its operation has been given in earlier reports (*4, 5*). Briefly, the test sequence is as follows: When the subject puts on the headphone set he hears a train of 4500 cps short tones in the test ear. Each short tone has a total duration of approximately 500 msec, and successive tones recur at the rate of one per second. A rise-decay time of approximately 20 msec assures essentially 'clickless' switching of the signal. By means of a 2 db step attenuator with a total range of 60 db, the subject adjusts the intensity of the 4500 cps short-tone train to threshold. The tester then depresses a key which simultaneously turns off the 4500 cps tones and turns on a continuous 3000

cps tone at a particular SPL in the test earphone. After 60 seconds the fatiguing tone automatically goes off and the 4500 cps short tones return to the test phone at a level 20db above the pre-fatigue threshold level. Simultaneously, two timer clocks are automatically turned on. The subject now listens for the return of the short tones in the test ear. When he has heard exactly two tones in succession, he depresses a lever which simultaneously decreases the intensity of the short tones by 10 db and stops one of the two timer clocks. The elapsed time read from this clock measures recovery time to within 20 db of the pre-fatigue threshold. The subject continues to listen until he again hears two tones in succession. He then depresses a second lever which stops the second timer clock. The reading from this clock measures recovery time to within 10 db of the pre-fatigue threshold level.

In the present experiment this entire sequence was repeated three times in succession. Immediately after the subject depressed the second lever, indicating that his threshold had returned to within 10 db of the pre-fatigue level, the 3000 cps fatiguing tone was reintroduced to the test ear, and the entire sequence repeated. This was followed by still a third sequence when the threshold had returned to within 10 db after the second fatiguing tone. Cumulative fatigue at either the 20 db or the 10 db level was then defined as the difference between recovery time measured after the first fatiguing tone and recovery time measured after the third fatiguing tone. All of the experimental measurements, cumulative or absolute, are thus expressed in seconds of recovery time.

The 26 experimental subjects were all young adult university students with normal hearing in both ears. They ranged in age from 19 through 29 years with a median age of 20 years. Twenty-four of the 26 subjects were female. Each subject was seen in six separate one-hour experimental sessions. A typical session consisted of three successive 'fatigue runs'; that is, recovery times were measured following each of three successive presentations of the fatiguing tone.

In succeeding sessions the identical procedure was followed, but the intensity level of the fatiguing tone was changed. A total of six fatiguing intensities was employed: 85, 90, 95, 100, 105, and 110 db (SPL *re* .0002 microbar developed in NBS No. 9-A coupler). The successive order in which these six levels were presented over the six experimental sessions was randomized separately for each subject. In order to minimize the possibility that long-term cumulative effects might carry over from one session to the next, a minimum of 24 hours separated all successive sessions. As a further precaution it was specified that no experimental condition be continued unless the subject's initial or pre-fatigue threshold was within 6 db of the threshold setting given by him at the start of his first experimental session. As it happened, this problem never arose in practice. Apparently, the 24-hour rest periods between sessions were sufficient to insure the absence of long-term confounding effects.

## Results

As noted earlier, cumulative fatigue is herein defined as the difference between threshold recovery time after

the first fatiguing tone and threshold recovery time after the third fatiguing tone. Two measures of this cumulative effect were available for analysis: (1) the difference in the time required for threshold to return to within 20 db of the pre-fatigue level; (2) the difference in the time required for threshold to return to within 10 db of the pre-fatigue level. In the following sections each of these measures is analyzed separately.

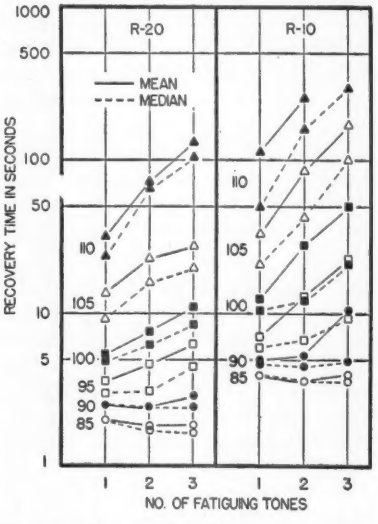


FIGURE 2. Mean and median recovery times for all experimental conditions.

Figure 2 summarizes all of the experimental data. The left side of the graph shows both mean and median recovery times for recovery to within 20 db of the pre-fatigue threshold as a function of the number of prior fatiguing tones. The parameter is the SPL of the fatiguing tone. The right side of the figure presents the analogous data for recovery to within 10 db of the pre-fatigue threshold. The mean recovery time after the third fatiguing tone at an SPL of 110 db is not represented because some subjects failed to return to the 10 db level within five minutes after termination of the third fatiguing tone, at which point the test procedure was arbitrarily terminated. It should be further noted that recovery time is represented on a logarithmic scale, a factor which tends to minimize the apparent degree of the cumulative effect but which was necessary in order to include all of the data within a single figure.

Inspection of Figure 2 suggests two generalizations: (1) A cumulative effect on recovery time over three successive fatiguing tones is clearly manifest at an SPL of only 95 db and grows more pronounced as the SPL is increased. (2) The advent of this cumulative effect is accompanied by a gap between mean and median recovery times, indicating that the distribution of recovery times becomes skewed in a positive direction. Again, the fact that recovery times are

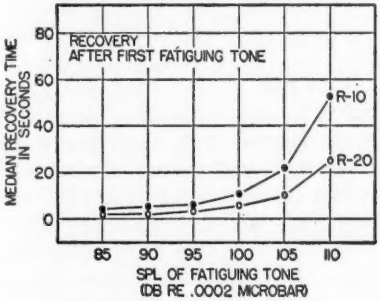


FIGURE 3. Median recovery time after first fatiguing tone as a function of fatiguing intensity.

plotted logarithmically tends to minimize the apparent degree of asymmetry. Because of this marked skew, the median and semi-interquartile range have been used to describe central tendency and variability, respectively, throughout the remainder of this report.

In order to seek explicit answers to the four experimental questions posed above, the data of Figure 2 have been recast in various ways in the following sections.

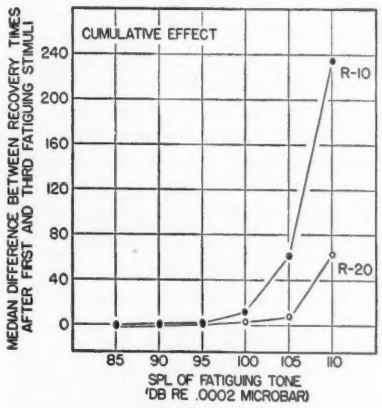


FIGURE 4. Median cumulative recovery time as a function of fatiguing intensity.

*Relation to Fatiguing Intensity.* Figures 3 and 4 illustrate the effects of fatiguing intensity on both absolute recovery time (recovery after first fatiguing tone) and the cumulative effect. In the case of absolute recovery time (See Figure 3) the functions for both R-10 and R-20 are relatively smooth and increase gradually with slight positive acceleration above an SPL of 100 db. The two corresponding functions for the cumulative effect (See Figure 4), however, exhibit sharp breaks. For R-10 the cumulative effect increases only slightly up to an SPL of 100 db and then accelerates rapidly. A similar change occurs at an SPL of 105 db in the R-20 function.

These abrupt breaks in the intensity functions are of theoretic interest in terms of the 'critical intensity' concept of auditory fatigue previously advanced by Hood (*3*) and more recently by both Rüedi (*8*) and the writer (*6*).

Hood (*3*) noted a break in the function relating temporary threshold shift to fatiguing intensity. Threshold shift increased only slightly as the fatiguing intensity was increased up to a sensation level of about 95 db. Above this 'critical level,' however, threshold shift increased markedly with further increase in fatiguing intensity.

Rüedi (*8*) has also observed this critical level phenomenon. He defines the critical intensity, however, not as the break in the function relating fatiguing intensity to threshold shift, but as the fatiguing intensity just below which the threshold recovery curve is characterized by a marked narrowing of the range between the just-heard point and the just-not-heard point (the so-called difference limen at threshold).

The writer (*6*) observed a similar critical intensity phenomenon in connection with the behavior of the two-minute 'bounce' in the threshold recovery function following fatiguing stimulation. As long as the intensity of the fatiguing stimulus remained below an SPL of 100 db, the bounce

TABLE 1. Rank-order correlation coefficients estimating relationships among cumulative effects measured after different SPLs of fatiguing tone for recovery times to within 20 db (R-20) and 10 db (R-10) of the pre-fatigue threshold (N = 26).

| SPL | SPL | | | | |
|---|---|---|---|---|---|
| | *90* | *95* | *100* | *105* | *110* |
| *R-20* | | | | | |
| 85 | .19 | −.18 | .36 | .28 | −.25 |
| 90 | | .49* | .54* | .06 | .06 |
| 95 | | | .40* | −.03 | .39* |
| 100 | | | | .49* | .12 |
| 105 | | | | | .26 |
| *R-10* | | | | | |
| 85 | .22 | .24 | .12 | −.05 | −.56* |
| 90 | | .63* | .45* | .41* | −.04 |
| 95 | | | .73* | .39* | .23 |
| 100 | | | | .68* | .22 |
| 105 | | | | | .36 |

*Exceeds value required for significance at the 5% level.

declined and ultimately disappeared from the recovery curve.

The present report shows this same critical intensity phenomenon in still another form, as a sharp break in the function relating degree of cumulative threshold recovery time to the SPL of the fatiguing tone.

*Correlations between Cumulative Effects at Various Intensities.* In order to determine the extent to which the cumulative effects at various fatiguing intensities were intercorrelated, rank-order correlation coefficients were computed for each possible pair of fatiguing intensities for both R-10 and R-20. Table 1 summarizes the results of these analyses in the form of correlation matrices.

The outstanding generalization to be drawn from these matrices is that the intercorrelations are, on the whole, rather weak. An individual coefficient is significant at the 5% level, which was chosen as a reasonable rejection criterion in this situation, only if it equals or exceeds .39. Inspection of Table 1 shows that coefficients were seldom of this magnitude and then only for relatively similar fatiguing intensities. At R-20, for example, only two of the five significant correlation coefficients occur for intensity differences greater than 5 db. The cumulative effect at 90 db correlates significantly with the cumulative effect of 100 db, and the correlation of .39 between 95 and 110 db just meets the rejection criterion. For all other intensity differences of 10 or more db, the coefficient fails to reach the significant level. Of further interest is the fact that the remaining three significant correlations, for intensity differences of 5 db, are all confined to the 90-105 region. Except for the coefficient of .39 noted above, the cumulative effects at neither 85 db nor 110 db show significant correlations with the cumulative effects at any other intensities.

A similar situation exists at R-10. Again, the significant coefficients are almost entirely confined to intensity differences of 5 to 10 db and cluster in the 90 to 105 region. Interestingly enough, the correlation between 85 and 110 db is significant here, but it is *negative* indicating that a large cumulative effect at 85 db is associated with a small cumulative effect at 110 db, and vice versa.

While it is hazardous to generalize extensively from these correlations, the conclusion does seem warranted that the cumulative effects evoked by one level of fatiguing intensity may bear no useful predictive relation whatever to the cumulative effects evoked by another level. More spe-

TABLE 2. Rank-order correlation coefficients estimating relationships among absolute recovery times measured after different SPLs of fatiguing tone for recovery times to within 20 db (R-20) and 10 db (R-10) of the pre-fatigue threshold (N = 26).

| SPL | SPL | | | | |
|---|---|---|---|---|---|
| | *90* | *95* | *100* | *105* | *110* |
| *R-20* | | | | | |
| 85 | .15 | .43* | .47* | .24 | .14 |
| 90 | | .28 | .22 | .03 | −.18 |
| 95 | | | .73* | .24 | .33 |
| 100 | | | | .24 | .10 |
| 105 | | | | | .45* |
| *R-10* | | | | | |
| 85 | .07 | .39* | .21 | .08 | .15 |
| 90 | | .38 | .32 | .02 | .04 |
| 95 | | | .54* | .16 | .37 |
| 100 | | | | .22 | .02 |
| 105 | | | | | .49* |

*Exceeds value required for significance at the 5% level.

cifically, the cumulative effect measured after a fatiguing intensity of 110 db appears to be quite unrelated to the cumulative effect measured after a fatiguing stimulus only 5 db less intense.

In view of the relatively weak intercorrelations among the cumulative effects measured after various fatiguing intensities, it is of some interest to examine the intercorrelations among *absolute* recovery times after different fatiguing intensities. Table 2 summarizes the correlation coefficients for both R-20 and R-10 after the first fatiguing tone. Here the over-all picture is even less encouraging. At R-20 only four of the 15 intercorrelations are significant and these four suggest no particular pattern.

In summary, then, both absolute and cumulative recovery times showed somewhat weak intercorrelations for different fatiguing intensities. These findings imply that the establishment of a relationship between 'short-term fatigue' and susceptibility to long-term damage from noise exposure may be critically dependent on the exact intensity level of the fatiguing stimulus used to measure the threshold shift.

A question of further interest is the extent to which the degree of cumulative effect might be predicted from the absolute recovery time. To this end rank-order correlation coefficients were computed between recovery time after the first fatiguing tone and the cumulative effect. Table 3 summarizes those correlation coefficients for both R-20 and R-10 at each fatiguing intensity. Examination of these coefficients reveals a significant positive relationship at intensities of 95 db and above. At 90 db, however, the coefficients, while still positive, fail to reach the rejection criterion of the 5% confidence level. Interestingly enough, at 85 db both coefficients are negative. At R-10 the coefficient is not significant, but at R-20 the negative value of .48 exceeds the 5% confidence level.

The significant positive coefficients at 95, 100, 105 and 110 db indicate that subjects showing the largest ab-

TABLE 3. Rank-order correlation coefficients estimating relationships between absolute and cumulative effects measured after different SPLs of fatiguing tone for recovery times to within 20 db (R-20) and 10 db (R-10) of the pre-fatigue threshold (N=26).

| | SPL | | | | | |
|---|---|---|---|---|---|---|
| | *85* | *90* | *95* | *100* | *105* | *110* |
| *R-20* | −.48* | .15 | .57* | .77* | .37 | .63* |
| *R-10* | −.27 | .29 | .71* | .60* | .54* | .73* |

*Exceeds value required for significance at the 5% level.

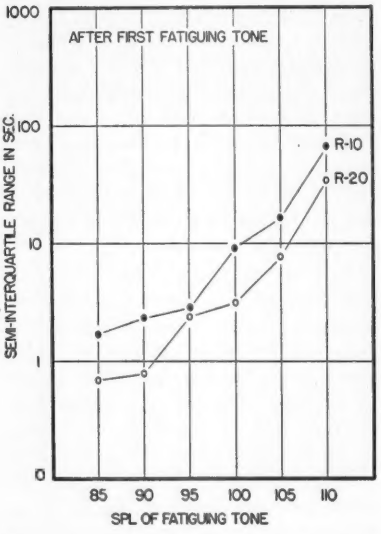


FIGURE 5. Variability of recovery time after first fatiguing tone as a function of fatiguing intensity.

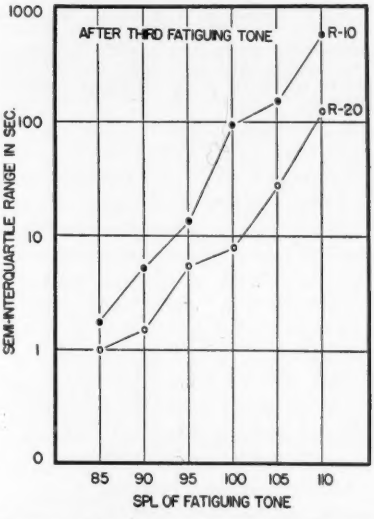


FIGURE 7. Variability of recovery time after third fatiguing tone as a function of fatiguing intensity.

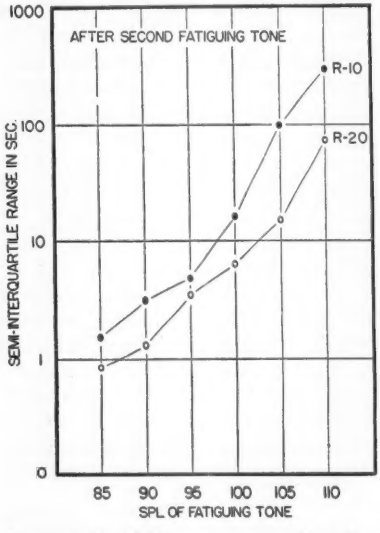


FIGURE 6. Variability of recovery time after second fatiguing tone as a function of fatiguing intensity.

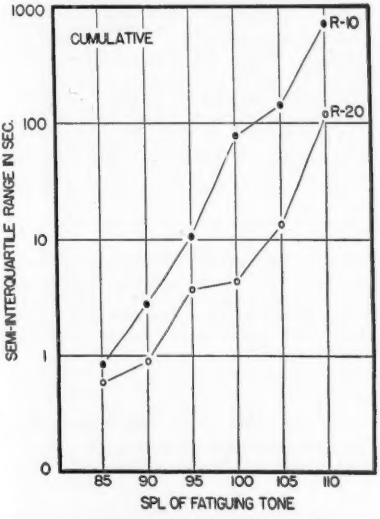


FIGURE 8. Variability of cumulative recovery time as a function of fatiguing intensity.

solute recovery time after a single fatiguing tone will also tend to show the greatest degree of cumulative effect. The relatively low magnitude of these coefficients, however, limits the extent to which one might safetly consider the two measures interchangeable.

*Intersubject Variability*. In order to evaluate the effect of fatiguing intensity on the intersubject variability of both absolute and cumulative recovery time, semi-interquartile ranges were computed for both R-20 and R-10 under all experimental conditions. In Figure 5 these indices of variability are plotted against fatiguing intensity for absolute recovery time after the first fatiguing tone. Figures 6 and 7 show analogous curves for recovery time after the second and third fatiguing tones, while Figure 8 illustrates the effect of fatiguing intensity on the variability of the cumulative effect.

Three generalizations are suggested by examination of Figures 5 through 8: (1) The R-10 measure is consistently more variable than the R-20 measure and the degree of the disparity increases markedly with fatiguing intensity. (2) The intersubject variability of both measures increases to an extremely marked degree as the fatiguing intensity is increased from 85 db to 110 db. Again, the fact that the semi-interquartile range is plotted on a logarithmic scale tends to obscure the relatively large increase that occurs as the fatiguing intensity is raised. (3) The variability of the cumulative effect is greater than the variability of the absolute recovery time after a single fatiguing stimulus. At the 110 db fatiguing intensity, for example, the semi-interquartile range for R-10 is 79 seconds, while for the cumulative effect it increases to over 700 seconds.

*Relation between Cumulative Effect and Threshold Sensitivity*. Whether the fatiguing effect produced by an intense auditory stimulus is more nearly determined by its sensation level or by its intensity level has been a matter of some controversy in recent years. Harris (*2*), in studying the recovery function after a single fatiguing stimulus, observed that, for a fatiguing stimulus of given intensity, the temporary threshold shift was greater for subjects with relatively low threshold sound pressure levels and less for subjects with less keen sensitivity. This led him to conclude that the magnitude of the fatigue effect was related to the sensation level rather than to the intensity level of the fatiguing stimulus.

In view of this finding the data were evaluated to determine whether a similar situation could be demonstrated with respect to the cumulative effects obtained in the present study. Rank-order correlation coefficients were computed between the magnitude of the cumulative effect and the initial or pre-fatigue threshold SPL. The ranking was done in such a way that a negative coefficient would indi-

TABLE 4. Rank-order correlation coefficients estimating relationships between cumulative effect and pre-fatigue threshold SPL* for recovery times to within 20 db (R-20) and 10 db (R-10) of the pre-fatigue threshold (N=26).

| | *SPL* | | | | | |
|---|---|---|---|---|---|---|
| | *85* | *90* | *95* | *100* | *105* | *110* |
| *R-20* | .01 | −.09 | .41† | .43† | .19 | .17 |
| *R-10* | .23 | .20 | .48† | .06 | −.06 | .00 |

*Positive correlation indicates that cumulative effect increases as threshold SPL increases.

†Exceeds value required for significance at the 5% level.

cate an association between acute threshold sensitivity (low threshold SPL) and a large cumulative effect. Hence, a significant negative correlation would indicate that sensation level rather than intensity level was the primary determinant of the degree or magnitude of the cumulative effect, while lack of significant correlation would imply that minor differences in the sensation level of the fatiguing stimulus from one subject to another did not influence the cumulative effect.

Table 4 lists these correlation coefficients for both R-10 and R-20 at each fatiguing intensity. All coefficients are relatively low. Only three exceed the 5% confidence level, and they are positive rather than negative. These results imply that minor differences in the sensation level of the fatiguing stimulus exerted no significant effect on the degree of cumulative fatigue. Indeed, where correlations were significant, at fatiguing intensities of 95 to 100 db, their positive sign suggests that greater cumulative effects may tend to be associated with poor threshold sensitivity. In any event, Harris's (2) finding on the relative importance of sensation level *versus* intensity level is not paralleled in the present data.

## Summary

The cumulative effects of repeated 3000 cps fatigue-producing stimuli on threshold recovery time at 4500 cps were explored at six intensity levels of the fatiguing stimulus (80, 85, 90, 95, 100, 105 and 110 db *re* .0002 microbar) in 26 normal ears.

Results demonstrated a cumulative effect on recovery time at SPLs of 95 db and higher. Functions relating cumulative effect to fatiguing intensity exhibited sharp breaks in the 100 to 105 db region, suggesting, in still another form, the critical intensity phenomenon so often demonstrated in other fatigue measures.

Intercorrelations between both absolute and cumulative effects at different fatiguing intensities were, on the whole, rather weak. Significant correlations were almost entirely confined to intensity differences of 5 to 10 db, and the 90 to 105 db region. Apparently the cumulative effects evoked by one level of fatiguing intensity may bear no systematic relation to the cumulative effects present at another level.

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# Estimation Of Formant Band Widths From Measurements Of Transient Response Of The Vocal Tract

Arthur S. House

Kenneth N. Stevens

A study of the transient response of the vocal tract was undertaken to provide information about the band widths of vowel formants and vocal tract damping. The study was motivated by the belief that detailed knowledge of the resonance band widths of the vocal tract should provide a clearer picture of the theory of vowel production and of the sources of energy loss in the vocal tract, and would, therefore, lead to a more thorough understanding of the requirements that must be specified for the successful electronic synthesis of high-quality speech. The need for such an investigation was strengthened, furthermore, by the presence of disparate data (*1, 2, 5, 9, 10*) in the literature pertaining to the subject.

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## Procedure

The method of measurement was to observe the rate of decay of the output of a human vocal tract when it was excited by a transient acoustic signal. At the top of Figure 1 is shown the transient that would be obtained when a system having a single resonance, that is, an electric circuit or an acoustic system having a single resonance, is excited by an impulsive source. The output of such a system has the form given by the equation. At the bottom of the figure is shown the spectrum of the output of such a system when it is excited by a broad-band acoustic source. The spectrum has a peak at the frequency of resonance $f_o$, and the band width $\Delta f$ is related to the decay constant $\sigma$ as shown in the figure. If the system in question is similar to the human vocal tract and has several resonances, these resonances generally can be separated by means of broad-band filters; decay curves of the type shown at the top of the figure are representative of only one resonance. In essence, Figure 1 delineates the relation between the rate of decay of the sound radiated by a system like the vocal tract and the band width of the resonance of the system.

In the present experiment the vocal cavities were excited by an impulsive

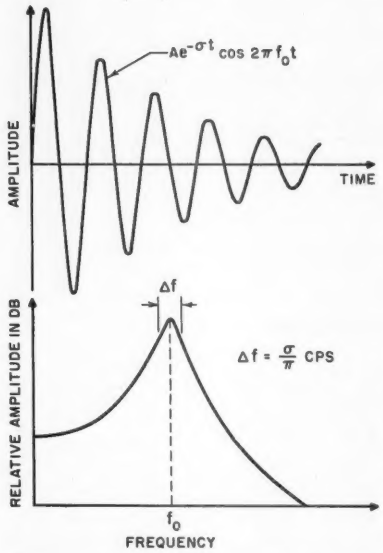


FIGURE 1. The impulse response (upper curve) and frequency response (lower curve) for a simple resonant system. The equation for the time function is shown together with the formula relating band width Δf and decay constant $\sigma$.

acoustic source (click) generated by a spark gap situated at one end of a thin probe. The location of the spark gap is shown roughly in Figure 2; the particular location selected for the source does not influence the decay constants for the various resonances.

The experimental procedure called for phonating a given vowel sound

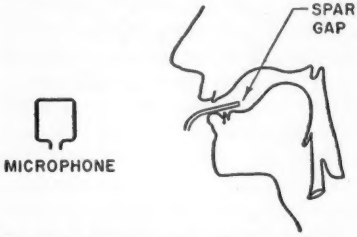


FIGURE 2. Location of spark gap and microphone.

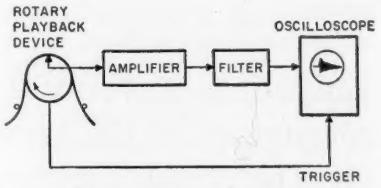


FIGURE 3. Arrangement of equipment used to analyze recorded transients.

to establish an articulatory configuration (as well as to identify the recorded data), inserting the probe while the articulators were relatively immobile, forming the spark, and recording the resulting acoustic end-product on magnetic tape. Transients were recorded for eight vowel configurations, that is, articulatory configurations appropriate to the production of the American English vowels /ɪ/, /ɛ/, /æ/, /ɑ/, /ɔ/, /ʊ/, /ʌ/, /ɝ/. For each vowel configuration the vocal system was excited with the glottis both open and closed. Three adult male subjects provided two samples of each vowel for each of the two glottal conditions. The transient data (and the identifying vocalizations) were recorded on a high-quality magnetic tape system. The microphone and subjects were situated in a sound-treated room and the recording system was in an adjacent control room.

The recorded transients were processed in a manner epitomized in Figure 3. The recorded samples were played back on a rotating-head device, and the output of this system was amplified and passed through a relatively broad band filter that was tuned to each resonance in turn. The transient response of the filter was short compared with the transient response of the vocal cavities and did not influence the measurement of the decay constants. The output of the

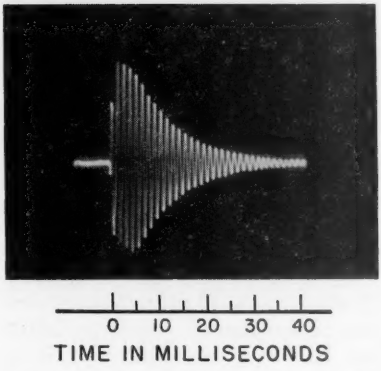


FIGURE 4. Typical photograph of a transient processed in the manner shown in Figure 3.

broad-band filter was diplayed on an oscilloscope with a calibrated sweep and a photograph of the display was taken. A typical photograph is shown in Figure 4.

The analysis of the photographic data was carried out by fitting a curve of the form $e^{-kx}$ to the decay portion of each signal. To facilitate the analysis a number of curves of the form $e^{-kx}$ with values of 1/k ranging between 1.25 cm and 3.50 cm in 0.25 cm steps were constructed and used to form a calibrated overlay that was superimposed upon the various photographs. The half-power band width of the resonance is equal to $k/\pi T$ cycles per second, where T is the sweep time of the oscilloscope trace in seconds per cm and k is in $cm^{-1}$. Since the value of the parameter k and the sweep time of the oscilloscope were known, the half-power band width of the resonance excited by a given transient was deducible from this formula, and was expressed to the nearest five cycles per second.

## Results

While the resonance band widths were the particular interest of the study, it can be noted that the center frequencies of the resonances of the vocal tract appeared at expected frequencies, except for the close vowel configurations where the low resonances were raised in frequency (presumably because their articulation was not close enough). Approximately 10% of the collected data were not measurable and do not figure in the discussions below.

The results of the band-width measurements demonstrate good agreement among the three subjects. The data in Table 1, for example, show that each subject provided smaller resonance band widths in the closed-glottis condition, and increasingly larger band widths for higher-frequency resonances. The mean values in the table demonstrate that the resonance band widths for the eight vowel articulations differed for the two conditions of glottal closure. This finding

TABLE 1. Mean half-power band widths (B1, B2, B3) in cycles per second for the first three resonances of vocal tract configurations. Three male subjects (S1, S2, S3) used eight vowel configurations with two glottal conditions.

| *Band Width* | *Open Glottis* | | | | *Closed Glottis* | | | |
|---|---|---|---|---|---|---|---|---|
| | *S1* | *S2* | *S3* | *Mean* | *S1* | *S2* | *S3* | *Mean* |
| B1 | 79 | 75 | 67 | 73 | 56 | 50 | 56 | 54 |
| B2 | 88 | 82 | 75 | 81 | 67 | 62 | 61 | 65 |
| B3 | 97 | 98 | 83 | 94 | 76 | 66 | 64 | 70 |

TABLE 2. Mean band widths (B1, B2, B3) in cycles per second for the first three resonances of vowel configurations. Data were averaged for three male subjects for closed-glottis condition.

| *Band Width* | /ɪ/ | /ɛ/ | /æ/ | /ɑ/ | /ɔ/ | /ʊ/ | /ʌ/ | /ɝ/ |
|---|---|---|---|---|---|---|---|---|
| B1 | 66 | 67 | 73 | 53 | 41 | 39 | 40 | 55 |
| B2 | 75 | 96 | 92 | 60 | 40 | 39 | 47 | 70 |
| B3 | 76 | 88 | 103 | 66 | 46 | 47 | 64 | 69 |

is predicted on physical grounds since additional energy loss results when the open glottis provides coupling to the trachea. The open-glottis condition thus yields broader resonance band widths than the closed-glottis condition.

It would not be appropriate to average the data obtained from the open-glottis and closed-glottis conditions to serve as approximations to the formant band widths of natural vowels. First, it is known that the duration of the open and closed phases of glottal vibration during phonation are not, in general, equal. In addition, the open-glottis condition of this experiment probably represents a larger glottal opening than would occur during phonation of a vowel. Furthermore, the air-flow effects at the glottis during phonation provide marked changes in energy loss at the glottis (*11*). Finally, the two extreme conditions of this experiment theoretically should provide slightly different resonance frequencies. If such a change occurs during the glottal cycle in vowel production, then the so-called average formant band widths that an experimenter could measure would differ from the values provided by both of the conditions in Table 1. As a matter of fact, the resonance frequencies for the open-glottis condition in this experiment tended to be higher than the closed-glottis values, but the data do not permit accurate specification of the differences.

The variation of resonance band width from vowel to vowel was fairly consistent from subject to subject. The data, summarized in Table 2, show a trend for the configurations for the vowels /ɛ/ and /æ/ to produce broader band widths than the other vowels, and for the back-vowel articulations /ɔ/ and /ʊ/ to produce the narrowest band widths. Since the number of samples of each vowel was small, no firm conclusions can be drawn from these findings.

TABLE 3. Comparison of mean band width data from different investigations. Tabular entries are in cycles per second. Columns are as follows: A, data from present study obtained with closed glottis; B, data from van den Berg *10*); C, data from Lewis (*5*); D, data from Bogert (*1*); E, data from Tarnóczy (*9*).

| *Band Width* | *Investigations* A | B | C | D | E |
|---|---|---|---|---|---|
| B1 | 54 | 55 | 39 | 130 | 110 |
| B2 | 65 | 66 | 51 | 150 | 190 |
| B3 | 70 | 89 | 80 | 185 | 260 |

Table 3 displays band-width values from this study and those reported by four previous investigators. The present data obtained in the closed-glottis condition agree most closely with the values reported by van den Berg (*10*), who made frequency and band-width measurements of the output from the vocal tract of a hemi-

laryngectomized subject when a loudspeaker source was placed on the laryngeal fistula. The resonances of the output were observed by sweeping the frequency of a sine-wave oscillator used as a source of excitation. The mean values tabulated in the second column were derived from his reported data by selecting arbitrarily three appropriate resonances for each of 11 vowels.

In 1936, Lewis (*5*) reported band-width values for five vowels produced by trained vocalists. He applied Fourier methods and utilized the sweeping characteristics of the vibrato to obtain his spectrum envelopes. Finally curves of simple-tuned filter responses were fitted to his data by inspection. The band widths from this study were slightly smaller than the present estimates and are shown in the third column of Table 3. It is believed, however, that Lewis' technique of fitting simple symmetrical resonance curves to the harmonic spectrum tends to yield band-width values that are too low. On theoretical grounds (*3*) it can be argued that the resonance curves actually should be tilted in such a way as to emphasize the low frequencies. Close examination of Lewis' published figures suggest that somewhat higher band widths would be obtained if such asymmetrical curves were fitted to his data.

The Bogert (*1*) values shown in the fourth column of Table 3 were derived from the speech samples of 33 talkers used as subjects in the Peterson and Barney (7) study. Samples involving 10 vowels were selected in a quasi-random fashion, and envelope curves were fitted to the amplitude-frequency displays, that is, sections, produced by standard methods of sound spectrography. The mean band widths resulting from these measurements are two to three times as broad as those of the present investigation and those reported by van den Berg and Lewis. One would expect, however, that the technique used by Bogert would yield band-width values that are higher than the true resonance band widths, since no effort was made to control the changes in formant frequency and in vocal frequency during the measurements.

The band-width values in the extreme right-hand column of Table 3 were reported by Tarnóczy (*9*). They are based on oscillographic data the collection of which involved having subjects vary vocal frequency in order to sweep a signal sufficiently to describe the resonance curves of the vocal cavities. As a control for this experiment, Tarnóczy collected some data in a manner similar to the procedures used in the present study. The band widths produced by spark excitation of the cavities, however, are highly similar to those attributed to Tarnóczy in Table 3. In these experiments, Tarnóczy apparently was seeking only orders of magnitude for the band widths, since many of his data are given to one significant figure only. Detailed comparison of his data with the results of later investigators is thus not warranted.

## Discussion

The data on formant band widths obtained in the present study are consistent with direct computations of damping in the vocal tract. There are several sources of energy loss in the vocal tract: (a) sound energy radiation from the mouth opening; (b) absorption of sound by the walls of

the vocal tract; (c) loss of sound energy at the glottal opening; (d) absorption of sound in the nasal cavity, which has much higher losses than the vocal tract; and (e) loss due to viscosity at the walls, particularly when there are narrow constrictions in the tract. For the relatively open vowel configurations studied here, with closed glottis and presumably closed velum, the principal losses can be attributed to the first two sources listed, that is, to radiation from the mouth, and absorption by the walls of the vocal tract.

In the approximate calculation of these losses the vocal tract was assumed to be a uniform circular tube 17 cm long and 5 $cm^2$ in cross-sectional area. The closest approximation to this configuration for the vowels listed in Table 2 is given by /æ/ (*8*). The radiation impedance is assumed to be that of a piston in a sphere of 9 cm radius (*2*, *6*), a valid assumption in the frequency range of interest. The specific acoustic impedance of the walls of the tract can be estimated from the data of Franke (*4*) on the impedance of the body surface at various points. It is assumed here that the walls of the tract behave like a resistance of about 4000 rayls (dyne-sec/$cm^3$) in series with a mass of about 0.4 gm/$cm^2$.

The band-width calculations follow conventional transmission-line theory, as given by Morse (*6*), for example, and the details will not be given here. The calculations are approximate and are intended only to indicate the relative importance of some of the effects that contribute to vocal-tract losses. More detailed calculations of losses for a number of vocal-tract configurations recently have been given by Fant (*2*).

The results of the computations are summarized in Table 4. The agreement between measured and computed band widths is reasonably good, in view of the approximate nature of the calculations. It is observed that the contribution to $\Delta f$ due to radiation losses is negligible at low frequencies, but increases sharply (proportional to $f^2$) as the frequency f increases. The contribution from wall losses is greatest at low frequencies and decreases with increasing frequency. For the first two formants, at least, the tendency is for the two effects to counterbalance, yielding a band width that is almost constant.

When the vocal folds are vibrating, there will be some losses at the glottal opening, and these will increase the effective band widths. Calculations of the glottal losses are difficult to make in view of the uncertainties concerning such variables as the exact dimensions and flow velocities. To a first approximation, however, the glottis can be represented by a series inductance and resistance, the average a.c. resistance and inductance being of the order of 200 acoustic ohms and 0.01 gm/$cm^4$ respectively (*11*). Computations show that the additional band

TABLE 4. Summary of calculation of band widths (B1, B2, B3) in cycles per second for a uniform vocal-tract configuration similar to /æ/. Computed frequencies of first three formants for uniform tube are 500, 1500 and 2500 cps. Columns as follows: A, computed band widths attributable to radiation losses; B, computed band widths attributable to absorption losses; C, computed band widths for radiation and absorption losses; D, measured band widths for /æ/.

| *Band Width* | *A* | *B* | *C* | *D* |
|---|---|---|---|---|
| B1 | 2 | 70 | 70 | 73 |
| B2 | 30 | 40 | 70 | 92 |
| B3 | 80 | 20 | 100 | 103 |

width contributed by this glottal impedance would be approximately 20 cps at low frequencies, and would be smaller than this at high frequencies, at least for the assumed idealized vocal-tract configuration. This result depends to some extent on vowel intensity and on vocal frequency.

For configurations other than the simple uniform tube, the computed band widths would be different, and would probably tend to have slightly smaller values (See Table 2). Calculations of expected band widths for non-uniform configurations are rather long and detailed and have not been carried out.

In summary it would appear that the mean band widths of the lowest three vocal resonances, including the effects of glottal losses, are of the order of 20 cps greater than the band widths given in Table 2. The ranges of band widths are, therefore, 60 to 90 cps for the first formant, 60 to 110 cps for the second formant, and 70 to 120 cps for the third formant. Thus, in the design of a speech synthesizer, the most natural-sounding vowel outputs should be obtained if these formant band widths are used. A listening test to verify this conclusion is in progress.

## Summary

As a means of determining the half-power band widths of the formants of vowel sounds, the impulse response of the human vocal tract was measured. The vocal cavities were excited by an impulsive acoustic source generated by a spark gap situated at one end of a thin probe. The probe was inserted into the mouth while the articulators assumed various vowel configurations, and the responses were recorded on magnetic tape. The decay rates for the various resonances were measured and the resonance band widths were deduced. The band-width data were compared to the experimental literature and to calculated estimates of formant band width. The sources of damping in the vocal tract were discussed briefly.

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# GSR Magnitudes For Different Intensities Of Shock, Conditioned Tone And Extinction Tone

E. Harris Nober

The galvanic skin resistance reflex (GSR) is recorded as a decrease in resistance to electrical conductivity at the surface of the body; it is generally considered to be caused by sweat gland activity mediated through the sympathetic network of the autonomic nervous system. There are two major techniques for obtaining the reflex: (1) the Féré technique, a change in skin resistance to an external source of current, and (2) the Tarchanoff technique, a measure of the electromotive force between two points on the skin. The former technique was employed in the present study.

Early attempts by audiologists to employ the GSR as the subject's involuntary response to an auditory stimulus failed, largely because the experimenters (*3, 15, 16*) used the tone as an unconditioned stimulus, and the unconditioned GSR extinguished after a few stimulations because of adaptation. More recent investigators (*1, 7, 8, 9*) have used the tone as a conditioned stimulus and the GSR as the conditioned response and have been consequently more successful. However, during the conditioning process an extra variable was added, the unconditioned stimulus, usually shock. The present study is concerned with the magnitude of the responses during the conditioning and extinction processes in relation to the intensities of the variables. In conditioning experiments this relationship has a crucial effect on habit strength, which, in turn, has important implications for both learning theory and clinical application.

The relationship between the intensity of the stimulus and the magnitude of the response has been studied primarily by experimental psychologists. Hovland and Riesen (*12*) reported a linear relationship between the intensity of the unconditioned stimulus and the magnitude of the unconditioned response. Hull (*13*) in his theory of learning posits a monotonic relationship between the intensity of the conditioned stimulus and the magnitude of the conditioned response; this relationship was subsequently labeled *stimulus intensity dynamism.* Habit strength was considered to depend upon the strength of the stimulus trace, which was a function of the intensity of the stimulus. In less tech-

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nical terms, stimulus intensity dynamism simply implies that there is a direct relationship between the intensity of the stimulus and the magnitude of the response, that is, as stimulus intensity increases response strength increases, and conversely. Hull (*13*) cited the results of several studies (*2, 10, 11, 14, 17, 18*) that supported his postulates. Grant and Schneider (*5, 6*) reported a trend in the direction of stronger conditioning with greater stimulus-intensity but the trend was not statistically significant.

The many theoretical advantages of GSR audiometry for special purposes have perpetuated the audiologist's relentless endeavor to perfect the technique. A major deterrent to its use is the disconcerting lack of reliability, which has been attributed to many variables, such as the subject's emotional state, apparatus, areas of the body used, and the audiologist's technique and interpretation of the data. There is little doubt that all of these and many other variables, if they are not carefully controlled, will significantly affect the GSR. The outstanding contributions of Hardy and Pauls (*7, 8*) and Doerfler (*4*) toward standardization of the procedure along with the recent availability of commercial instruments specifically designed for evaluating auditory acuity have improved the technique as a clinical tool. But even with the recent standardization of apparatus and technique, the GSR is not completely reliable and is best used when interpreted as an approximation of the subject's auditory threshold rather than the absolute threshold.

The purpose of this study is to explore an inherent variable that may contribute significantly to the magnitude of the GSR—the *intensity* of the stimuli employed to elicit the reflex during the reinforcement and extinction processes. The study is based on the contention that if the Hullian concept of stimulus intensity dynamism is an operational entity, it is conceivable that the unpredictable variations in GSR may be related to the sensation levels employed to condition and extinguish the reflex responses.

## Procedure

The experiment was conducted in a physical setup that involved three adjacent sound-treated rooms: a testing room, a control room and a waiting room. The control room was located between the testing and waiting rooms and contained the testing equipment. The equipment consisted of a tone generator, a shock unit, a mechanical timer, and the galvanic skin resistance testing apparatus.

An ADC audiometer generated the 1000 cps tone. The shock source was two 135-volt batteries in series. A mechanical timer programmed the shock and tone durations in a predetermined fixed temporal contiguity. The tone always preceded the shock. The tone was on 0.6 second; during the final 0.2 second of this period and for an additional 0.1 second the shock was presented. The time of one pairing of stimulations of tone and shock was 0.7 second.

The GSR recording equipment was composed of four parts: (1) a decade resistance box, (2) a Brush D.C. amplifier, (3) an Esterline-Angus Graphic Ammeter Recorder and (4) eight thimble electrodes. The unit operated so that the voltage across the subject was proportional to his resistance.

Each subject was given a hearing check for the 1000 cps tone and only those subjects whose threshold did

not exceed 5 db were used. The range on the Esterline-Angus recorder was calibrated to enable the subject to function within a 20000 ohm range.

The GSR was derived from two measures, the base level and the stress level. The former was the point at which a sudden decrease in skin resistance to electrical conductivity occurred, and the latter was the point of maximum decrease. Both values, recorded in ohms, were converted to mhos by obtaining the reciprocal value of each. This conversion served to minimize the correlation between the reflex and the base levels. The difference between the base and stress levels was the reflex value, expressed as a mho. For convenience, the mho was multiplied by 1,000,000 and expressed as a micromho. The responses were averaged over a number of trials to obtain a criterion measure.

Subjects typically gave more reflex responses of small magnitude than of large magnitude. The data, therefore, were skewed toward the small-response end of the range. To obtain a more normal distribution of the data, the scores were logarithmically transformed. The techniques of analysis of variance were employed to evaluate the various treatment effects; the five per cent level of confidence was accepted as indicative of true differences among treatment population means. Prior to the analyses, both the raw and transformed data were tested for homogeneity of variance by the Bartlett test. In each instance the hypothesis of homogeneity was retained. Since the data were more nearly normally distributed after transformation, the transformed measures were employed.

Zero scores were occasionally elicited during the extinction trials. Since these scores did not yield to logarithmic transformations, a constant, +10, was added to each score used in the experiment and the resulting values were then multiplied by 10. The multiplication did not affect the mantissa of the logarithm but it increased the characteristic of the logarithm from 1 to 2. Prior to the analysis of variance, 2 was subtracted from each of the coded values.

The means enumerated in the tables and text were computed from the coded logarithmic data after they were reconverted or decoded to micromho units. A mean (y) was obtained by averaging the relevant mantissa values and systematically applying the equation,

$$y = \log 10\ (x + 10) - 2,$$

where $x$ is the mean, expressed as a micromho value of a criterion measure. The over-all means in the tables were computed from the logarithmic equivalents of the means in the columns and rows. Therefore, the over-all mean is not always equivalent to the arithmetic mean of the decoded micromho values in the columns and rows. For example, the mean values for the 30 db conditioned tone level were 1.89, 4.05 and 7.69 micromhos at the 30, 60 and 90 db extinction tone levels, respectively. The over-all mean computed from the coded logarithmic data was 4.35 in contrast to the mean, 4.54, of the decoded micromho values. Discrepancies of this nature occurred only when there was marked dispersion among the original data, that is, 1.89 to 7.69 in this instance. The logarithmic transformation reduced the effect of the extreme values. Generally, the data were homogeneous so that the dispersion among the values was small and the treated and untreated means were equivalent. For example, the mean

TABLE 1. Mean values of each stimulation trial (81 subjects pooled), expressed in micromhos. Reinforcement Trial 1 was considerably larger than the other eight; so only Trials 2 through 9 were averaged, for each subject, to obtain a value to represent strength of conditioning. Extinction Trial 1 was considerably larger than the other eight extinction trials; so it was used separately to represent initial habit strength while the mean of extinction Trials 2 through 9 represented resistance to extinction.

| *Trial Type* | *Trial Number* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* |
| *Reinforcement* | 5.74 | 3.81 | 3.27 | 3.17 | 3.17 | 3.12 | 2.91 | 2.98 | 2.63 |
| *Extinction* | 3.21 | 2.64 | 1.83 | 1.78 | 1.56 | 1.55 | 1.51 | 1.33 | 1.42 |

values for the 30 db extinction tone level were 1.89, 1.53 and 1.90 micromhos at the 30, 60 and 90 db conditioned tone levels, respectively. In this instance the over-all mean computed from the coded logarithmic data and the decoded micromho mean had the identical value, 1.77 micromhos.

The original experiment on which this paper is based involved 170 male Navy personnel, mostly cadets; it was divided into five parts, each using different methods to condition and extinguish the responses of the subjects. There were three variables: (1) the intensity of the shock, (2) the sensation level of the conditioned tone, and (3) the sensation level of the extinction tone. Since the results of the five parts substantiated each other, only the data and results from Part 1 will be presented in detail.

The data of Part 1 were obtained from 81 experimental subjects. The levels of conditioned tone were 30 db, 60 db and 90 db. Each conditioned tone was accompanied by one of three levels of shock: 0.54, 1.35 or 2.16 ma. The subject's responses were then extinguished with one of three intensities of the extinction tone. Thus there were 27 different combinations of the stimuli and three subjects who received any one combination of stimuli.

Each of the 81 subjects received nine reinforcement and nine extinction trials. The mean value of the 81 pooled responses for each trial was then computed; the results are summarized in Table 1. As the value of the first reinforcement trial (probably a startle response) was considerably higher than the values of the remaining eight, only Trials 2 through 9 were averaged to obtain the representative score. It is customary to refer to the value that represents the response strength during the reinforcement or conditioning trials (tone plus shock) as the *strength of conditioning*. The term used to represent the magnitude of the extinction responses (tone alone) is *habit strength;* this relates to the amount of learning that has occurred. Several terms can be used to represent habit strength but only two are employed here. Table 1 reveals that the first extinction trial value, 3.21 micromhos, was relatively larger than the remaining eight, so this response was used separately to represent the *initial habit strength*. The mean of the remaining eight was termed *resistance to extinction*, a value more frequently employed than the foregoing to represent habit strength. Consequently, there are two separate

TABLE 2. Summary of analysis of variance testing the effect of the intensities of shock and the conditioned tone on strength of conditioning.

| *Source* | *df* | *ss* | *ms* | *F* |
|---|---|---|---|---|
| Shock (S) | 2 | .05371 | .0269 | 10.35* |
| Tone (T) | 2 | .00556 | .0028 | 1.08 |
| S x T | 4 | .00315 | .0008 | 0.31 |
| Within Cells | 72 | .18983 | .0026 | |
| Total | 80 | .25225 | | |

*Significant at the 1% level.

TABLE 3. Mean values of strength of conditioning.

| *Conditioned Tone* | *Shock 1* | *Shock 2* | *Shock 3* | *Over-all** |
|---|---|---|---|---|
| *30 db* | 2.19 | 2.78 | 3.68 | 2.87 |
| *60 db* | 1.87 | 3.12 | 3.54 | 2.82 |
| *90 db* | 2.08 | 3.57 | 4.54 | 3.36 |
| *Over-all** | 2.05 | 3.16 | 3.91 | |

*The over-all means were computed from the logarithmic equivalents of the means in the columns and rows.

scores to represent habit strength, making available additional information concerning whether the magnitude of the GSR is related to the method used to quantify the data as well as to the intensity of the stimulus.

TABLE 4. Summary of two analyses of variance testing the effect of the intensities of shock, the conditioned tone and the extinction tone on habit strength.

| | *Source* | *df* | *ss* | *ms* | *F* |
|---|---|---|---|---|---|
| *Initial Habit Strength* | | | | | |
| | Shock (S) | 2 | .037 | .0185 | 1.73 |
| | Conditioned Tone (CT) | 2 | .085 | .0425 | 3.97* |
| | Extinction Tone (ET) | 2 | .124 | .0620 | 5.79† |
| | S x CT | 4 | .042 | .0105 | 0.98 |
| | S x ET | 4 | .006 | .0015 | 0.14 |
| | CT x ET | 4 | .066 | .0165 | 1.54 |
| | S x CT x ET | 8 | .072 | .0090 | 0.84 |
| | Within Cells | 54 | .577 | .0107 | |
| | Total | 80 | 1.009 | | |
| *Resistance to Extinction* | | | | | |
| | Shock (S) | 2 | .00647 | .00324 | 1.43 |
| | Conditioned Tone (CT) | 2 | .00558 | .00279 | 1.23 |
| | Extinction Tone (ET) | 2 | .03873 | .01937 | 8.53† |
| | S x CT | 4 | .02874 | .00719 | 3.17* |
| | S x ET | 4 | .01410 | .00353 | 1.58 |
| | CT x ET | 4 | .01075 | .00269 | 1.19 |
| | S x CT x ET | 8 | .01791 | .00224 | 0.19 |
| | Within Cells | 54 | .12232 | .00227 | |
| | Total | 80 | .24460 | | |

*Significant at the 5% level.
†Significant at the 1% level.

TABLE 5. Mean values of initial habit strength and resistance to extinction relevant to the intensities of the conditioned tone and the extinction tone (shock levels pooled).

| *Extinction Tone* | *Conditioned Tone* | | | *Over-all* |
|---|---|---|---|---|
| | *30 db* | *60 db* | *90 db* | |
| *Initial Habit Strength* | | | | |
| *30 db* | 1.89 | 1.53 | 1.90 | 1.77 |
| *60 db* | 4.05 | 3.43 | 1.88 | 3.09 |
| *90 db* | 7.69 | 4.83 | 2.07 | 4.67 |
| *Over-all* | 4.35 | 3.19 | 1.95 | |
| *Resistance to Extinction* | | | | |
| *30 db* | 1.34 | 0.70 | 0.69 | 0.91 |
| *60 db* | 1.32 | 2.28 | 1.27 | 1.61 |
| *90 db* | 2.86 | 2.20 | 1.98 | 2.33 |
| *Over-all* | 1.81 | 1.71 | 1.30 | |

## Results

Table 2 summarizes the analysis of variance relevant to strength of conditioning (reinforcement responses). The three shock levels produced statistically significant differences in the magnitude of the responses; the responses associated with the three intensities of the conditioned tone that accompanied the shock were not significantly different. The means relevant to strength of conditioning are summarized in Table 3. The means associated with the three intensities of Shock Levels 1, 2 and 3 showed significant and consistent increases from the lowest to the highest shock level.

During the extinction trials (See upper part of Table 4) the intensity of the conditioned tone and also of the extinction tone significantly affected the magnitude of the responses associated with initial habit strength (the first extinction trial). Differences among shock levels were not significant for initial habit strength.

The intensity of the extinction tone (See lower part of Table 4) significantly affected the magnitude of the responses associated with resistance to extinction (the mean value of extinction trials 2 through 9). Although the intensity of shock and also of the conditioned tone did not on the average affect resistance to extinction responses, their interaction was significant; that is, changes of response magnitude accompanying changes of conditioned tone were not the same from one shock level to another.

The means relevant to the two above-reported analyses of initial habit strength and resistance to extinction were averaged over the three levels of shock, the effect of which was nonsignificant for both analyses. These means are given in Table 5.

Means of initial habit strength increased consistently and significantly with increases of intensity of the extinction tone. They consistently decreased with increases of intensity of the conditioned tone; the differences were significant except for the decrease between the 30 and 60 db levels of conditioned tone. Although differences among shock levels were nonsignificant, the obtained means of 2.27,

3.25 and 3.78 micromhos were consistently larger with increasing shock level.

The means associated with resistance to extinction were larger with increased intensity of extinction tone and all differences among these three means were significant. Although the effect of intensity of conditioned tone on resistance to extinction was non-significant, the means decreased with increases of intensity of the tone. For the three shock levels for resistance to extinction, the trend of the means was similar to the trend of the corresponding means for initial habit strength, increasing from 1.41 to 1.46 to 1.96 micromhos with increasing shock level. The significant interaction between intensities of shock and the conditioned tone apparently was the result of a descending trend over the three shock levels for the 30 db conditioned tone (2.26 to 1.42 to 0.80 micromhos) and an ascending trend of the 90 db conditioned tone (0.08 to 0.78 to 2.49 micromhos).

## Discussion

The trends of (1) strength of conditioning relevant to the intensity of shock and (2) initial habit strength and resistance to extinction relevant to the intensity of the extinction tone revealed a direct relationship between stimulus intensity and response strength, as predicted by the doctrine of stimulus intensity dynamism. On the other hand, an inverse relationship between stimulus intensity and response strength occurred for the extinction responses that were tested against the intensity of the conditioned tone (extinction tone pooled), as shown in the column means of Table 5; for initial habit strength the means were 4.35, 3.19 and 1.95 micromhos while for resistance to extinction the means were 1.81, 1.71 and 1.30 micromhos at the 30, 60 and 90 db conditioned tone levels, respectively.

Parts 2, 3 and 4 of the experiment, not reported in detail in this paper, were largely extensions of Part 1. They differed only in terms of the techniques used to condition and extinguish the subject's responses. Various techniques were systematically applied to simulate the procedures used by the audiologist in the clinical situation. The results generally supported those described in Part 1 with one important exception. In Part 1 the intensity of the conditioned tone significantly affected the magnitude of the responses relevant to initial habit strength. This was the only instance in the total experiment when the effect of the conditioned tone had a statistically significant effect on either the reinforcement or the extinction responses; the atypically large responses of one subject apparently contributed to the significance of the results.

An outstanding finding of the total experiment was that the intensity of the extinction tone was invariably significant in affecting the magnitude of the extinction responses (habit strength); this relationship was a direct one, as posited by the doctrine of stimulus intensity dynamism. Of equal importance was the finding that the intensity of shock significantly affected the responses during the reinforcement trials but was generally non-significant during the extinction trials. The conclusion that stimulus generalization was minimal thus seems reasonable.

Part 5, not reported in detail in this paper, can be considered as supplying control group data for the experiment since the tone was presented alone as an unconditioned stimulus. The treat-

ment means associated with the three intensities of tone did not show a statistically significant *F* ratio, although the trend was consistent with that found in the other four parts. It is reasonable to assume, therefore, that the responses associated with the conditioned stimulus (the tone during the reinforcement and extinction trials) were specifically a result of the conditioning process rather than a general reaction to the inherent properties of the stimulus tone.

From the results of the five parts of the original experiment, it appears that response strength is a function of the intensity of the stimuli employed and the criterion measures used to quantify the responses, but in a specific way. For example, the intensity of shock significantly affected the responses during the reinforcement or conditioning trials but not during the extinction trials. The implication here for the audiologist is that he should avoid the inference that conditioning is stronger because the subject's response becomes greater with successive increments of shock (UCS) during the reinforcement trials. The trace effect of the unconditioned stimulus is negative during the actual testing procedure (or extinction trials) where it is not presented. The intensity of the conditioned tone (CS) never significantly affected the responses during the reinforcement trials and in only one instance affected the responses during the extinction process. The implication here for the audiologist is that the intensity of the conditioned tone accompanying the shock will not affect subsequent responses but it must be audible, of course, for conditioning to occur. There is no evidence, therefore, to support the use of traumatizing intensities of shock or conditioned tone during the conditioning process. Apparently, with this sample of subjects, a weak shock and a soft tone conditioned the individual as well as more intense stimuli.

The intensity of the extinction tone always had a significant effect on the responses during the extinction trials. The trend showed a direct relationship between stimulus intensity and response strength. The responses elicited from shock during reinforcement trials and extinction tone during extinction trials are not, therefore, all-or-none in magnitude but grossly reflect the intensity of the stimulus. Further investigation is being undertaken by the author to determine whether the responses associated with the recruitment factor correlate with the magnitude of the GSR.

## Summary

The effects of several intensities of shock, conditioned tone and extinction tone upon GSR magnitude were evaluated relative to strength of conditioning, initial habit strength and resistance to extinction. The magnitude of the responses associated with the reinforcement trials varied with the intensity of the shock stimulus while the responses associated with the extinction trials varied with the intensity of the extinction tone. The conditioned tone accompanying the shock never significantly affected the responses during the conditioning process and in only one instance affected the extinction responses. The trend of the GSR showed a direct relationship between stimulus intensity and response strength.

From the results of this study, the following implications for the audiologist may be drawn: The fallacious inference that conditioning is stronger because the GSR increases in magni-

tude, during the reinforcement trials, as the intensity of the unconditioned stimulus (shock) is increased, and conversely, should be avoided. The trace effect of the unconditioned stimulus (shock) is negative during the actual testing procedure (or extinction trials) where it is not presented. The intensity of the stimulus tone (extinction tone) used during the testing process (extinction trials) always has an effect on the magnitude of the GSR. The responses elicited from shock during the reinforcement trials and extinction tone during the extinction trials are therefore not all-or-none in magnitude but grossly reflect the intensity of the stimulus. There is no evidence to support the use of traumatizing intensities of shock or conditioned tone during the conditioning process. A mild shock and an audible tone will condition the individual as well as more intense stimuli.

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# Soft Palate Movement In Normals

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Velar activity makes an important contribution to the production of normal speech. The inability to effect adequate velopharyngeal closure results in escape of air through the nasal passages when production of speech sounds requiring intra-oral air pressure is attempted. Surgical and prosthetic treatment of cleft palate individuals is directed toward reduction of velopharyngeal inadequacy, because normal speech depends in part upon the ability to trap outward passing air for short periods of time.

This paper is based on a study undertaken for the purpose of compiling data on measurements of normal velopharyngeal activity with which to compare similar measurements of post-operative cleft palate patients. Observation of the manner in which the normal velum performs its function in speech is limited to trans-oral inspection unless x-ray techniques are employed. Inspection through the mouth seriously limits observations in two respects. First, with the mouth open only certain speech sounds, all of which are vowels, can be used, and, second, in a normal subject only the inferior surface of the velum can be seen. The site of velopharyngeal contact and the area on the pharyngeal wall where most activity takes place are completely shielded from view. X ray provides a means of viewing velopharyngeal activity from the lateral aspect, facilitating study of the movement of the posterior surface of the palate and its relationship to the wall of the pharynx. It must be borne in mind, of course, that the mid-sagittal laminagrams from which the data in this report are derived are only two-dimensional configurations.

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## Procedures and Equipment

Lateral laminagraphic skull films were made of 80 subjects whose speech was within the normal range and in whom examination disclosed no oral anomalies or gross skull malformations. Films were made of each subject at rest, phonating the vowel [ɑ], and producing the continuant consonant [s]. The latter condition was included because clinical observations of the difficulty post-operative cleft palate patients experience in correctly producing this sound suggest that normal production of [s] requires an extreme amount of velopharyngeal activity. The subjects were carefully prepared for the task, and trained personnel were present to listen and judge whether the sounds being produced were the phonemes which were desired. No judgements were made of the presence or absence of hypernasality or other voice

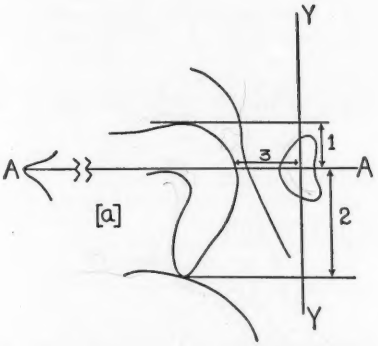


FIGURE 2. Line drawing of laminagram traced from laminagraph of subject phonating [ɑ]. Drawing shows main reference line, A-A, drawn from anterior nasal spine to midpoint of the tubercle of the atlas; the perpendicular, Y-Y, was erected at the midpoint of the tubercle. Measurements were made of (1) velar height above A-A, (2) distance of tip of velum below A-A, (3) distance from posterior surface of velum at selected level to Y-Y along line parallel to A-A.

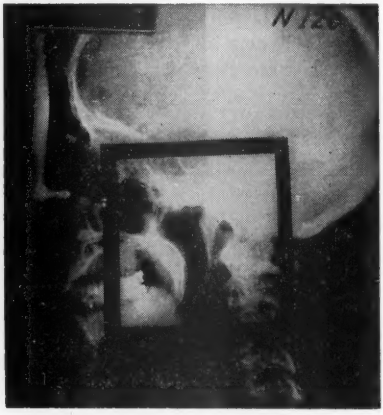

FIGURE 1. Conventional radiographic lateral skull film. Square depicts area shown in remaining figures.

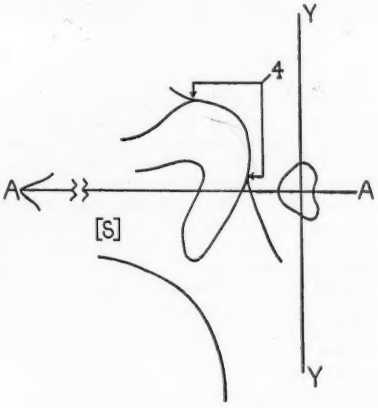


FIGURE 3. Line drawing of laminagram traced from laminagraph of subject saying [s]. Drawing shows how measurement of range of contact was obtained.

quality. Thirty of the subjects were Negroes, and 50 were white. Data were treated separately for these two groups because it seemed possible that differences might exist which would contaminate the results.

The equipment and procedures have been described at length in an earlier paper (*1*). Upright cephalometric laminagraphy was used to assure more accurate portrayal of structures and events at the mid-sagittal line, and all films were developed in an automatic unit to assure consistent results. Prior to taking the x rays, an oil-based radiopaque material was instilled in the nostrils of each subject and allowed to flow over the superior surface of the velum and the posterior pharyngeal wall to facilitate the making of tracings from the films.

Tracings were made of the portions of the films shown within the insets in Figure 1, and the main reference line, A-A in Figure 2, was drawn from the anterior nasal spine through the midpoint of the anterior tubercle of the atlas as suggested by Krogman (*2*). At the midpoint of the anterior tubercle a perpendicular to line A-A, designated Y-Y, was erected.

Four measurements were made from tracings of each of the three subject conditions: rest, [ɑ] and [s] (See Figures 2 and 3). These four measurements were as follows: (1) the maximal distance of the velum above line A-A; (2) the maximal distance of the velum below line A-A; (3) the distance from the posterior margin of the velum to line Y-Y at a selected level; and (4) the extent of velar contact with the posterior pharyngeal wall, namely, the distance from the most superior point of contact to the most inferior point of contact as measured along the line of contact (See Figure 3). A map measuring device was used to obtain this information.

The distance from the posterior margin of the velum to line Y-Y was measured at the level of the point of nearest approximation of the velum to the posterior pharyngeal wall during phonation of [ɑ]. The measurement was along a line parallel to line A-A. In those cases where the opposing surfaces were equidistant over an extent of several millimeters, a midpoint was selected. Utilizing this same level, similar measurements of the posterior excursion of the soft palate were made in the rest and [s] tracings. This method was devised in order that the posterior movement of the soft palate might be measured at its most active level in relation to the posterior pharyngeal wall rather than at an arbitrary level which might fall outside the area of greatest usefulness of palatal activity.

## Results and Discussion

Among the white subjects the superior surface of the velum averaged 2.73 mm farther above line A-A during phonation of [ɑ] than in the rest position. The range for [ɑ] was from 5.0 mm below to 9.5 mm above the rest position, with a standard deviation of 3.96 mm. The superior surface of the velum averaged 9.17 mm farther above line A-A for [s] than for rest. The range for [s] was from 2.0 mm to 18.0 mm above the rest position and the standard deviation was 3.53 mm. The superior surface of the velum averaged 6.44 mm farther above line A-A for [s] than

for [a]. The range for [s] was from 4.0 mm below the [a] position to 13.5 mm above, with a standard deviation of 3.76 mm.

The distance of the tip of the velum below line A-A averaged 4.8 mm less during phonation of [a] than in the rest position. This measurement ranged from 8.0 mm greater to 22.0 mm less for [a] than for rest, with a standard deviation of 5.72 mm. The distance of the tip of the velum below line A-A averaged 9.34 mm less during production of [s] than in the rest position. The range was from 1.0 mm greater to 23.0 mm less for [s] than for rest, with a standard deviation of 5.53 mm. The distance of the tip of the velum below line A-A averaged 4.54 mm less for [s] than for [a], with a range from 7.0 mm greater to 11.0 mm less and a standard deviation of 3.76 mm.

The mean reduction in distance from the posterior margin of the velum to line Y-Y from rest to [a] was 17.36 mm. The amount of this reduction ranged from 7.5 mm to 29.5 mm and the standard deviation was 5.47 mm. From rest to [s] the mean reduction was 19.02 mm with a range from 7.0 mm to 29.5 mm and a standard deviation of 5.61 mm. From [a] to [s] the mean reduction was 1.66 mm. The distance from the posterior margin of the velum to line Y-Y for [s] ranged from 4.0 mm greater than [a] to 10.0 mm less, and the standard deviation was 2.51 mm.

The average distance from the most superior to the most inferior point of velopharyngeal contact as measured along the line of contact in laminagrams of white subjects saying [s] was 23.0 mm. This measurement ranged from 50.0 mm to 5.0 mm and the standard deviation was 5.95 mm.

FIGURE 4. Laminagraph of area shown in inset in Figure 1, subject at rest position. The soft tissues have been outlined to provide for better clarity in the photographic reproduction.

Standard deviations were not computed for the measurements of the Negro group. Among the Negro sub-

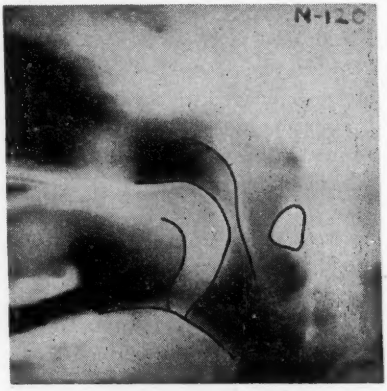


FIGURE 5. Laminagraph showing subject phonating [a]. Note how velum has moved posterosuperiorly. The soft tissues have been outlined to provide for better clarity in the photographic reproduction.

jects the mean amount of upward movement of the superior surface of the velum from rest to [ɑ] was 4.2 mm, and from rest to [s] it was 9.0 mm. The mean upward movement of the tip of the velum from rest to [ɑ] was 7.1 mm, and from rest to [s] 9.5 mm. The mean reduction in distance from the posterior margin of the velum to line Y-Y from rest to [ɑ] was 22.0 mm, and from rest to [s] was 23.8 mm. The velopharyngeal port was completely closed during phonation of [ɑ] in 15 of the 30 Negro subjects and closure was complete in [s] in all Negro cases. The average distance from the most superior to the most inferior point of velopharyngeal contact as measured along the line of contact in laminagrams of subjects saying [s] was 24.4 mm.

The mean amount of upward movement of the superior surface of the velum from rest to [ɑ] in the Negro group was 1.49 mm greater than the mean for the whites. From rest to [s] this movement was .1 mm greater on the average among the whites studied than among the Negroes, but in each of the four remaining measurements of excursion the mean was greater among the Negroes than whites, as follows: upward movement of the tip of the velum from rest to [ɑ], 2.3 mm; from rest to [s], .2 mm; posterosuperior movement of the velum from rest to [ɑ], 4.7 mm; from rest to [s], 4.6 mm. The mean extent of the distance from the most superior to the most inferior point of velopharyngeal contact as measured along the line of contact during production of [s] was also slightly greater among the Negro group. It appears that treating the data from the two groups separately was justified.

An example of the movement of the palate from rest through [ɑ] to complete velopharyngeal closure in the [s] position is provided by Figures 4, 5 and 6. These figures were taken from the lateral laminagraphic skull films of the subject whose conventional x ray is shown in Figure 1. In Figure 4 the velum (at rest) lies flaccidly on the posterior aspect of the tongue leaving a wide nasopharyngeal aperture. In Figure 5 the velum is elevated and carried posteriorly, narrowing the nasopharyngeal aperture during the phonation of [ɑ].

FIGURE 6. Laminagraph of subject saying [s]. Velopharyngeal contact is complete over a range greater than two centimeters. The soft tissues have been outlined to provide for better clarity in the photographic reproduction.

The distal end of the velum is usually angled anteriorly as shown. In Figure 6 the velum is pressed firmly against the posterior pharyngeal wall while the unused tip points even more anteriorly. Frequently, among the laminagraphs of the subjects saying [s], the velum maintained contact with

such apparent force that it displaced the pharyngeal wall posteriorly in the area of contact.

In the absence of a vigorous Passavant's bar, which was seen in only nine of the 80 subjects studied and was functional in only three, it seems evident that the soft palate participates far more aggressively than the posterior pharyngeal wall in regulation of the nasopharyngeal aperture during speech.

## Summary

Lateral cephalometric laminagraphs in the mid-sagittal plane were made of 80 normal subjects (50 white and 30 Negro) at rest, phonating [ɑ], and producing the continuant consonant [s]. Tracings were made of laminagraphs and a reference line was established from the anterior nasal spine to the midpoint of the anterior tubercle of the atlas. From tracings of each of the subject conditions, namely, rest, [ɑ] and [s], measurements were made of the maximal distance of the velum above the reference line and the maximal distance of the tip of the velum below the line. A perpendicular to the main reference line was erected at the midpoint of the tubercle, and the distance was measured from this perpendicular to the posterior surface of the velum at a selected level along a line parallel to the main reference line. All subjects showed complete velopharyngeal closure while saying [s], and the extent of velar contact with the posterior pharyngeal wall was determined and recorded.

The study was undertaken for the purpose of compiling data on measurements of normal velopharyngeal activity with which to compare similar measurements of post-operative cleft palate subjects.

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# Predicting Intelligibility Of Cerebral Palsied Speech

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This study is concerned with the prediction of the intelligibility of the speech of young adult cerebral palsied subjects from measures of their consonant articulation. The essential information used in this study included (a) a test of the consonant articulation of each subject, yielding data which provided both simple and complex articulation predictor measures, and (b) objective criterion measures of the word and sentence intelligibility of each subject. In addition to a determination of the intelligibility-predicting ability of each articulation measure, a supplementary objective included an analysis of the relationships among the various predictors and between the two criteria.

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## Procedure

*The Selection of Criterion Measures.* Any intelligibility score is a relative measure and is dependent upon the particular unit of speech being evaluated as well as the specific procedures used in the evaluation. Objective, quantitative measures which are obtained by counting the number of speech units, such as words and sentences, correctly recorded by the listener, give the most information (7). Objective intelligibility evaluations of speech units larger than a sentence are difficult to make. The procedure usually utilized for such longer units involves subjective ratings. While units of speech larger than a sentence are difficult to standardize and quantify by objective methods, samples of units shorter than words are difficult to utilize because of the inability to obtain an adequate range of values. The shorter the unit the more difficult it is to obtain high intelligibility values.

The Harvard PB (phonetically balanced) lists which were selected to measure word intelligibility for this study have been described in detail by Egan (7). These word lists have enjoyed extensive clinical use for the measurement of discrimination loss in

hard-of-hearing individuals. In addition, considerable information that is available relating scores on these tests to the hard-of-hearing subject's general communication adequacy in everyday situations supported a decision to use these lists in evaluating the communication adequacy of the defective speaker. The Harvard PB words are write-down type measures, that is, the listener writes down what he hears. Criticism of write-down tests in terms of difficulties in scoring has resulted in the development of other types of word tests (*2, 3, 11*). However, the difficulties in scoring these tests seemed not to be insurmountable, and, for the needs of the present study, the advantages of these measures outweighed this difficulty. Other write-down word tests, resulting from revisions of the PB lists (*13, 14*), presented an advantage in terms of greater familiarity of the words used, but the vocabularies did not appear to be large enough for the numerous repetitions of the lists which the design of this study required.

The Harvard SI (sentence intelligibility) lists (*1*) were utilized in this study. These are also write-down type tests. Some of the previously developed sentence intelligibility measures, such as the early Fletcher and Steinberg (*10*) tests, are likely to measure information available to the listener. Other sentence tests, such as the Hudgins' lists (*16*), have a scoring advantage since their comprehension can be indicated by a one-word answer, but they were not deemed likely to provide an adequate spread of scores suitable for the needs of this study. Abrams *et al.* (*1*) point out that the Harvard SI lists provide a greater spread of scores. The use of these lists in the present study seemed advisable particularly for that reason. In addition, these sentence lists were favored because of the larger number of lists available and the apparent comparability among lists. The present study utilized the same group of listeners for evaluating the intelligibility of all speaker subjects and it was therefore necessary to provide enough different, comparable lists so that the listeners did not need to hear any list more than once. These lists are presented and described in detail by Abrams *et al.* (*1*).

*The Selection of Predictor Measures.* Familiar words were selected to test the way in which each subject produced each of 24 consonant sounds in each word position in which the sound occurs. Also tested in familiar words were 21 selected frequently-occurring consonant blends. The majority of the words were selected from Fairbanks' suggested words for non-readers (*8*) and from tests for consonant combinations suggested by Johnson, Darley and Spriestersbach (*18*). The following 24 consonants were tested: [m], [p], [b], [w], [f], [v], [θ], [ð], [h], [tʃ], [n], [t], [d], [r], [s], [z], [j], [l], [ʃ], [ʒ], [dʒ], [ŋ], [k], [g]. The following 13 consonant blends were tested in the initial position of the word: [br], [dr], [tr], [kr], [gr], [pl], [kl], [st], [sp], [sk], [sm], [sn], and [sl]. The following nine consonant blends were tested in the final position of the word: [ts], [ns], [lt], [ld], [lk], [rk], [rn], [rt], and [rd]. Several 'predictor' measures were obtained by analyzing the results of this articulation examination.

The specific measures were of three types: (a) predictor measures based on complex analyses of an articulation test; (b) predictor measures based on simple analysis of an articulation test; and (c) criterion measures of intelligibility.

Predictor measures based on complex analyses of an articulation test were as follows: (a) an index, based on that suggested by Wood (*23*), weighted with respect to the frequency of occurrence in the English language of each consonant sound; and (b) an index based on Mader's (*20*) data concerning the frequency of occurrence of sounds in each word position in transcribed speech.

Predictor measures based on simple analyses of an articulation test were as follows: (a) a count of consonant sounds correctly produced, including common consonant blends; (b) a count of correctly produced single consonants (no blends included); (c) a count of correctly produced initial consonants only; (d) a count of correctly produced medial consonants only; (e) a count of correctly produced final consonants only; and (f) a count of the correct productions of the five front consonants, [p], [b], [m], [d] and [t], hereafter referred to as Irwin's test (*17*).

Criterion measures of intelligibility were as follows: (a) a measure of word intelligibility, utilizing the Harvard PB words (7); and (b) a measure of sentence intelligibility, utilizing the Harvard SI list (*1*).

*Subjects.* The previously described speech samples were obtained from 17 male and 12 female cerebral palsied subjects ranging in age from 17 to 49 years. They were recruited from the Pittsburgh and Philadelphia areas through the cooperation of the United Vocational Employment Service of Pittsburgh, United Cerebral Palsy Association of the Pittsburgh District, United Cerebral Palsy Association of Philadelphia and Vicinity, and the University of Pittsburgh Speech Clinic. These organizations were requested to supply young cerebral palsied adults who were (a) not mentally retarded, (b) ambulatory to the extent that they could come in or be brought in to a central location for recording, and (c) able to read reasonably well. The subject's ability to read the test materials was checked when the recording was done. Five of the 29 subjects who were used could not read the material. The data from the total group of 29 subjects, including these five non-readers, and data from the group of 24 subjects who could read the material were analyzed separately. A major objective in selecting subjects for this study was to obtain a wide range of speaking abilities resulting in an adequate spread of intelligibility scores.

*Obtaining the Speech Samples.* Speech samples were recorded on tape using a Magnecorder Model PT6-AH recorder with a Western Electric 633A microphone. High quality tape and a tape speed of 7.5 inches per second were used.

Each subject was recorded separately in the presence of one of the experimenters and an assistant. During the recording the experimenter kept the microphone at a distance of approximately eight to 10 inches from the subject's face. The assistant kept

the recording at a constant level as indicated by a V.U. meter at the recorder. Speech samples were obtained in the following order: first, a connected speech sample[1]; second, the words comprising the articulation test material; third, the PB list; and fourth, the SI list.

Each subject was asked to read the connected speech sample silently and, if he did not understand any word, to ask about it. He was then asked to read the first sentence aloud and to stop at the end of this sentence. At this point the experimenter determined whether or not the subject was to be considered as a reader or a non-reader. The decision was made on the basis of the subject's apparent understanding of the entire selection and his reading of the first sentence. If the experimenter was uncertain about the decision, he asked the subject to read and explain the meaning of words from a PB list different from the one randomly selected for this subject.

The experimenter identified subject and sample by recording on the tape the words, 'This is subject number —, intelligibility A.' When signaled to do so, the subject read the remainder of the sample. Each of the speech samples was identified on the tape in a similar manner immediately prior to the subject's reading of the sample. The schedule for each subject was as follows: (a) A connected speech sample was obtained in the manner indicated above. (b) Subject was given approximately three minutes rest. (c) Subject read silently the entire list of articulation test words and then recorded the words as they were presented to him, one at a time on cards, at five-second intervals. (For the non-readers, the recording volume was turned down during the five-second interval between words, during which time the experimenter read the word aloud. The subject then repeated the word.) (d) Subject was given 10 minutes rest, during which time he walked around and talked with the experimenter. (e) Subject read over PB list silently and then recorded PB words, presented to him one at a time on cards, at five-second intervals. (f) Subject was given five minutes rest. (g) Subject read over SI sentences silently and then recorded sentences. All sentences were presented to him on one sheet of paper. Sentences were recorded with 30-second intervals between them.

Because the words in the articulation test were simpler and more familiar than the PB lists and the SI sentences, and because the subject was required first to read all lists silently, no practice aloud appeared necessary. For each test (articulation words, PB lists and SI sentences) the experimenter recorded the test item number before each word or sentence. The subject spoke only the word or sentence.

*Auditing the Speech Samples.* Tapes for all listening sessions were played over a Magnecorder pickup and PT6-J amplifier which fed eight high-fidelity speaker systems. One speaker system was located in each of the eight corners (four near the floor and four near the ceiling) of a room approximately 10′ x 22′ in size. Sound level meter readings indicated that the speaker arrangement provided approximately equal intensity at each listening position in the room. The room

[1]The connected speech sample provided data which are not reported in this study.

was not soundproof but was treated inside with heavy rug pads placed on the floor and hung from scaffolding placed around each wall. These provided an effective means of cutting down reflected sound waves from the hard wall surfaces of the room. The listening sessions were conducted at a time when external noise was at a minimum.

Speech samples comprising the articulation test were played to a group of five graduate students in speech and hearing disorders. The nature of the recordings was explained and procedures for scoring were discussed before the auditing was done. The examiners were given a training period during which samples of various types of articulatory disorders, using cerebral palsied speakers not included in the study, were presented. The instructions were presented again at the beginning of the first auditing session. Questions and discussion were permitted. During listening sessions, which varied in length from two to four hours, rest periods were frequent.

The sound production of each subject was rated by each articulation examiner on the following five-point scale: *1*, correct production, *2*, omission, *3*, mild distortion, *4*, severe distortion and *5*, substitution. However, for the analyses used and reported in the present study only a two-point scale was used. The four types of errors were combined into one category, incorrect production. The examiners were requested not to discuss their evaluations with each other. They were encouraged to have the word replayed if, for any reason, they were not sure of their evaluation.

The recordings of the PB lists and the SI sentences were played to a group of 10 listeners, nine females and one male. All the listeners except one were graduate students in education. The one exception was a college senior in education. The same listeners heard all subjects. The listeners' hearing and listening abilities were checked on a sample of the same type of material as that which they were to audit. After a training period, described in the next paragraph, the group listened to a list of the PB words and a list of the sentences which had been previously recorded by a normal speaker. All the listeners earned a score of 100% on the sentence test. Eight listeners earned a score of 100% on the PB words, one earned 96% and one earned 90%. All of the listeners continued to participate in all the listening sessions, but the data supplied by the listener who obtained 90% on the PB list were not utilized in the study.

During the first listening session instructions were given to the listeners and a training period of approximately two and one-half hours was conducted. Frequent rest periods were provided. The listeners were instructed regarding the nature of the study, the nature of materials to be heard, and the responses which were expected of them as auditors. The following specific instructions concerning the auditors' responses to the word and sentence lists were discussed:

> The words in the word list are all one-syllable words. Some of them will probably be more familiar to you than others. You are requested to write down the word you think the subject read. If you are not sure how to spell the word, write it like it sounds. Sometimes there

> may be instances where there are two or more words which sound alike but are spelled differently. In these instances it doesn't make any difference which word you record. Keep in mind that the main object is to write down the word you think the subject is trying to say. If you do not know what the subject says or are not sure, you are requested to guess.
>
> The sentence lists contain sentences that are not related to each other in any way. Any kind of word may appear in the sentences; they are not all of one syllable like the word lists. If you do not know what the sentence is or are not sure, guess if you have any ideas. If you hear part of the sentence but not all of it, try to fill in the rest of it by guessing if you have any idea what it might be.

After the instructions were discussed and questions answered, the listeners were given intensive training in listening to cerebral palsied speakers reading both PB and SI lists. During the training period no speech samples were used from subjects who contributed data to the experiment.

The remaining listening sessions were three hours in length and were conducted on consecutive days, with the exception that one week-end intervened between two of the sessions. The speech samples were randomized by subject. The following schedule was adhered to during each listening session: Subject 1, words followed by three to five minutes rest; then sentences followed by at least five minutes rest; Subject 2, words followed by three to five minutes rest, then sentences followed by 15 to 20 minutes rest. The procedure outlined for Subject 1 was repeated for Subject 3, the procedure for Subject 2 was repeated for Subject 4, and the remaining subjects were scheduled in a similar fashion. The number of subjects heard during any one three-hour listening period varied from four to six, depending primarily upon the speaking rate of the subjects and the extent of their speech involvement.

All speech samples were presented at a loudness level which the listeners reported to be loud but not uncomfortably loud. No measurement of the intensity level was made.

*Scoring the Tests.* The articulation test was scored as follows: each subject's production of each sound was scored as merely *correct* or *incorrect.* If a majority (three or more) of the articulation examiners had evaluated a sound as incorrect, it was scored as incorrect. If a majority had judged it to be correct, the sound was scored as correct.

Eight articulation scores, comprising the eight different predictor measures, were then determined for each subject. The basis of all scores was the number of correct sounds produced by the subject.

The PB word lists written down for each subject by each of the nine listeners were scored independently by two judges. Each of the judges was a graduate student with at least basic training in phonetic transcription. Each of the listener's written responses for each subject was compared against the key list of words which the subject had read during the recording procedure. The criterion for a correct score on each word was that the word written by the listener be phonetically equivalent to the key word. For purposes of scoring, the [ʍ] was considered as phonetically equivalent to [w]. The two judges agreed in their decisions 99% of the time. Disagreements were discussed and an arbitrary decision was made in each case. The

PB intelligibility score for each subject was determined by averaging the scores given that subject by each of nine listeners.

Each SI list (20 sentences) supplied by each of nine listeners for each of the 29 subjects was compared independently by two judges with the appropriate key sentence list. Each of the 20 sentences on the list contained five key words. The following instructions were used by the judges in scoring the sentences:

> Only the key words are scored. In order for a key word to be considered correct, it must be phonetically equivalent to the underlined key word on the key sheet and it must be in the proper order in the sentence *in relation to the other four key words*. Thus, if a listener has added additional words in a sentence or left out non-key words, it is still possible for each of the key words to be correct. If two key words are phonetically correct but reversed in order, they are incorrect.

The two judges agreed in their decisions 99% of the time. The disagreements were re-evaluated and arbitrarily resolved by one of the judges.

The final sentence intelligibility score for each subject was determined by averaging the scores provided by scoring each of the nine listener's responses for that subject.

*Nature of the Remaining Data Analyses.* The agreement among the articulation examiners was determined by calculating the percentage of agreement among the five examiners on the total number of decisions made. The inter-listener reliabilities for the PB and SI lists were determined separately by utilizing analysis of variance procedures.

All predictor scores were determined and each was correlated separately with the PB word and the sentence intelligibility criteria. In addition, correlations were calculated among the predictors and between the two criterion measures.

All correlations were calculated twice, once for the total group of 29 subjects and once for the group of 24 readers only.

## Results

*Agreement Among the Articulation Examiners.* The percentages of agreement among the articulation examiners ranged from 80% to 88% for consonant blends only; from 86% to 91% for single sounds only; and from 85% to 90% for singles plus blends. The reliability of the articulation examination was considered satisfactory.

*Reliability of the Intelligibility Test Auditors.* The inter-listener reliability for the nine intelligibility auditors was calculated separately for the word and sentence tests, using analysis of variance procedures. The original formula for use in this instance is Fisher's intra-class formula (*19, 21*). Ebel (*6*) compared the use of the intra-class formula with average intercorrelation and with generalized reliability formulas and concluded that the intra-class formula is the most convenient and generally useful. For purposes of the inter-listener reliability estimates in the present study, it was more convenient to use an intra-class formula than to calculate average intercorrelations. Estimates of the reliability of a single listener's set of scores for the PB test was .97 and for the SI test .98. For purposes of the present study it is justifiable to use the formula for reliability of combined scores because the final criterion intelligibility score for each subject is

TABLE 1. Pearson *r*'s obtained for evaluating relationships among longer predictor measures and criterion measures.

| *Variables** | *Mader's Index* | *Wood's Index* | *Singles and Blends* | *Single Sounds Only* | *PB Score* |
|---|---|---|---|---|---|
| SI Score | .88 | .88 | .87 | .89 | .90 |
| Mader's Index | | .99 | .97 | .97 | .88 |
| Wood's Index | | | .98 | .98 | .91 |
| Singles and Blends | | | | .99 | .90 |
| Single Sounds Only | | | | | .91 |

*SI and PB scores are criterion measures. The other four variables are predictor measures.

based upon an average of the combined ratings of the nine listeners. For both PB and SI tests, this reliability estimate is .99.

*Correlations Among the Variables Studied.* The relationships among the variables were studied by calculating Pearson product-moment correlations. In order to insure against unwarranted conclusions because of the inclusion of the five non-readers, all correlations were calculated separately for the total group of 29 subjects and for the readers-only group of 24 subjects. Results were practically identical in each of the two groups. For this reason only the correlations for the total group are reported. In general, it appears that the inclusion of the five non-readers in the analysis is justified and that the modifications in the experimental design necessary to include them did not materially alter the results. The subsequent relationships among the predictor and criterion measures are discussed with reference to the correlations resulting from the data obtained from the total group of 29 subjects. The correlations resulting from the data provided by the total group are reported in Tables 1 and 2.

*Predictors of PB Word Intelligibility.* The correlation between each set of articulation scores obtained from the four longer tests and the PB word intelligibility scores are shown in Table 1. These correlations

TABLE 2. Pearson *r*'s obtained for evaluating relationships among shorter predictor measures and criterion measures.

| *Variables** | *PB Score* | *SI Score* | *Single Consonants* |
|---|---|---|---|
| Initial Sounds Only | .86 | .79 | .96 |
| Medial Sounds Only | .90 | .90 | .97 |
| Final Sounds Only | .88 | .88 | .96 |
| Irwin's 5 Consonants | .68 | .80 | .80 |

*SI and PB scores are criterion measures. The other five variables are predictor measures.

indicate a decided relationship between each of the articulation scores and the PB word intelligibility criterion. Inspection of the four correlations warrants the conclusion that there is no apparent advantage of any one of the articulation measures over the others for prediction of PB word intelligibility. Merely counting the number of single consonant sounds correctly provides a score which predicts this criterion as accurately as measures which are much more elaborate and time consuming. This result is similar to that of Falck (*9*), who found no difference between an error count and a Wood-type index in prediction of intelligibility of cleft palate speakers. Further support for the conclusion that each of these articulation measures predicts the PB criterion equally well comes from the correlations they have with each other. Table 1 shows that the correlations among these four articulation measures range from .97 to .99.

Even much shorter and simpler articulation examinations predict PB word intelligibility as accurately as the longer tests. Table 2 presents the correlations between each of four short tests and the PB criterion. The correlation between the PB score and a score based on the number of correct initial sounds is .86. PB scores correlated with scores based on correct medial sounds yields an $r$ of .90. PB scores correlated with scores based on correct final sounds results in an $r$ of .88. The correlation between the PB score and scores resulting from testing only the [p], [b], [m], [t] and [d] is .68. It will be observed that the first three correlations are of the same general order of magnitude as the correlations of the longer articulation measures with the PB criterion shown in Table 1. The indications seem to be that even the very short tests, with the exception of Irwin's test, predict the intelligibility criterion as effectively as the elaborate ones.

The correlation of .68 between Irwin's test and PB word intelligibility requires some explanation. This correlation is not of the same order of magnitude as other correlations discussed. The difference between this correlation of .68 and the correlation of .91, between correctly produced single consonant sounds and the PB criterion measures, was found to be statistically significant. The difference here may also be large enough to be of practical importance. The correlation of .68 is, however, statistically different from zero at well beyond the one per cent level of confidence. This correlation seems to indicate that this test predicts the PB word intelligibility of the subjects in this study considerably better than chance but not as accurately as the other predictor measures evaluated. If this is true, there are several possible explanations for the failure of this test to predict the criterion measures as well as the other measures. For the subjects used in the present investigation, this test failed to provide a wide range of scores. The distribution of the subjects' scores on this test was highly skewed. Ten of the 29 subjects, for example, made no errors at all on this test and eight subjects made only one error. With one variable skewed to this extent, the product-moment correlation will be low. However, since a count of the correct productions of these five front consonants apparently results in highly

skewed data when used with the type of adult cerebral palsied subjects who participated in this study, there seems to be no point in attempting to show increased correlation by other means.

No test of a possible statistically significant difference between any of the other pairs of correlations seems indicated. The magnitudes of these correlations are large and very similar. The correlations reported indicate that, for purposes of predicting PB intelligibility, the shorter tests are as efficient as longer measures. This seems to be true even though reported studies indicate that speech-handicapped subjects are inconsistent in their errors (*22*). Each of the three scores–initial only, medial only and final only–results from sampling the subject's ability to produce each single consonant only once. Because some of the single consonant sounds do not appear in all three positions, one or two fewer sounds may be sampled in the tests based on initial-only and final-only sounds. These results support a conclusion that the use of cumbersome longer tests, particularly elaborately weighted indexes, is not necessary in research projects where the prediction of word intelligibility is the objective of the test.

Since the shorter tests (with the exception of Irwin's test) seemed to predict the PB scores as well as the longer ones, the results were correlated with the scores based on single sounds in all positions in order to evaluate further the relationships between such short tests and the longer ones. These correlations, shown in the third column of Table 2, are very high (.96, .97 and .96) and offer support to the conclusion that the shorter tests seem to measure much the same entity as the longer ones.

*Predictors of Sentence Intelligibility.* Table 1 shows the correlations between the sentence intelligibility criterion measures and each set of measures obtained by the previously discussed longer articulation tests. Each set of these articulation scores is highly correlated with the sentence intelligibility criterion measures. Again, inspection of the correlation coefficients is sufficient to justify the conclusion that none of these articulation measures shows any particular advantage over the others in terms of prediction of the sentence intelligibility criterion. Further inspection shows also that each of these predictor measures predicts the measures for the particular sentence criterion used in this investigation about as well as it predicts PB word intelligibility measures.

Table 2 reports Pearson *r*'s obtained for evaluating relationships between the four shorter tests and sentence intelligibility. The scores based on testing medial sounds only and final sounds only appear to predict the sentence criterion as well as any of the longer tests. The correlations based on initial sounds only and Irwin's Test are slightly lower but are of a magnitude which may be considered acceptably high. The conclusion that relatively simple tests based on error counts predict sentence intelligibility as adequately as elaborate weighted indexes seems justified.

*Relationship Between PB Word Intelligibility and Sentence Intelligibility Measures.* Table 1 shows the correlation between PB word intelligibility

scores and sentence intelligibility scores to be .90. This correlation indicates a substantial relationship, which is not surprising. Hudgins (*14*) reported a strong relationship between word and sentence intelligibility in measuring the speech of the deaf. Although Abrams *et al.* (*1*) report that the complexity of speech behavior required in speaking sentences may attenuate the correlation between word and sentence measures, the difficulty in speaking sentences may actually have operated to increase the correlation in the present study. Sentence intelligibility, because of contextual clues and other such variables, is almost always expected to be higher than word intelligibility (*1*, 7, *12*) and, in studies such as that of Hudgins (*14*), the range of sentence intelligibility scores is smaller than the range of word scores. This would operate to decrease the correlation between the measures. In the present study the ranges of the SI scores and PB scores were practically the same. It is possible that the difficulties encountered by the cerebral palsied subjects in making longer and more complex speech responses may have partially overcome the advantages of contextual clues present in sentences. DiCarlo (*5*), Cypreanson (*4*) and others have obtained results which show that defects of rhythm in cerebral palsied speakers contribute to intelligibility difficulties. Hudgins and Numbers (*15*) concluded, in studying the intelligibility of deaf subjects, that rhythm contributed as much to the intelligibility variance as did consonant sound production. It may happen, as DiCarlo (*5*) suggests, that even the redundancy in the speech of some cerebral palsied individuals may be unintelligible, thus negating the advantages to intelligibility of the redundancy present in longer speech samples. Nevertheless, sentence intelligibility is highly predictable from word intelligibility in these subjects.

Another matter of interest emerging from the results of this study is that the difference between word and sentence scores is not as great as the difference between these measures reported for normals (7, *12*) or for the deaf subjects studied by Hudgins (*14*). We would expect this result if the cerebral palsied subjects have more difficulty with longer speech responses. It is also probable that the sentence intelligibility criterion used in this study is more closely related to word intelligibility than are other types of sentence intelligibility measures.

The scoring of the sentences proved to be burdensome and expensive in time. The PB words seem to provide a more acceptable intelligibility criterion, and from them sentence intelligibility can be quite accurately predicted. This conclusion seems to be supported by the conclusion of Hudgins (*14*) that sentence intelligibility can be predicted from PB word intelligibility with a relatively small amount of error.

## Summary

The primary purpose of this study was to compare, in terms of their efficiency as predictors of intelligibility, several complex and several simple measures of the consonant articulation of young adult cerebral palsied subjects. Tape recorded speech samples, obtained from 29 subjects, were audited by five speech clinicians

who evaluated each subject's articulation ability and by nine listeners who wrote down what they understood of each subject's intelligibility recordings. Prediction of intelligibility by each of eight articulation measures was evaluated by correlating each set of predictor or articulation measures with each set of criterion or intelligibility measures.

The two intelligibility measures (PB or word intelligibility and SI or sentence intelligibility) were predicted as well by any one of three short simple articulation test measures (initial consonant sounds only, medial consonants only, and final consonant sounds only) and by two longer simple articulation test measures (all single consonant sounds and all single consonant sounds plus consonant blends) as by the two more complex, weighted indexes (a Wood-type articulation index and the Mader index). The results of Irwin's short test of five consonants failed to predict the intelligibility measures as well as the results of the other five simple articulation tests. Word intelligibility and sentence intelligibility were predicted about equally well by any one of the several articulation measures.

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# Harshness And Glottal Attack

Maryjane Rees

Abrupt or glottal initiation of vowels, according to the literature on voice disorders, may be one of the variables associated with harsh voice quality. According to Fairbanks (*9*), 'A common accompaniment of harshness is the habitual use of glottal stops or clicks at the initiation of vowels.' Craig and Sokolowsky (*6*) have stated, 'Glottic shock (glottal catch or glottal stop) is caused by an oversharp attack upon an initial vowel. Its excessive and continuous use gives the entire speech a characteristic harsh timbre . . . '

It has been a commonly held tenet in the literature on harshness that laryngeal tension is one of the etiologic agents for this type of voice quality disorder (*1, 2, 3, 4, 5,* 7, *9, 10, 11, 12, 14, 16, 18, 19, 20*). Moore's (*13*) motion picture study of vocal fold operation, in which he was searching for the cause of the glottal stroke or glottal shock, demonstrated that laryngeal tension and this type of vowel initiation are, at least to some extent, related. He has stated, 'The so-called stroke attack involves more constriction in the superior laryngeal musculature than the breathed or simultaneous attacks.'

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Investigation of the abruptness with which vowels produced by speakers with harsh voices are initiated could serve two purposes. If a strong positive relationship between abruptness of vowel initiation and harshness were demonstrated, then a major concern in the treatment of harshness would be the elimination of this type of vowel attack. Furthermore, a strong positive relationship between these two variables would be indirect evidence of a relationship between at least one type of laryngeal tension and harshness.

## Procedure

This study was a portion of a larger project designed to evaluate the influence of several variables on the perception of harsh voice quality. The description of the selection of 12 speakers with harsh voices and the method of obtaining scale values of the severity of harshness from responses of 32 listeners have been reported in detail earlier (*15*).

*Experimental Material.* The stimulus material for the present study consisted of recordings of the following isolated vowels: [i], [ɪ], [ɛ], [æ], [ʌ], [ɑ], [ɔ], [ʊ] and [u]. These nine vowels produced by each of the 12 harsh voices, 108 vowels in all,

were dubbed from the original tape which had been prepared for the larger project (*15*). A Presto RC 10/24 and a Concertone Model 1401 were used. The vowels were arranged in random order with the restriction that no two vowels from the same voice appear adjacent to each other.

*Judging Abruptness of Vowel Initiation.* The same 32 listeners who rated severity of harshness also judged the 108 isolated vowels for the presence or absence of abrupt initiation. They first heard a verbal description of abrupt initiation. Next they listened to two training tapes. These tapes were recorded by five male graduate students in speech pathology and were judged to be suitable for their purpose by another five graduate students in speech pathology. The first tape consisted of recordings of 45 abruptly initiated vowels. The second tape consisted of a series of 15 vowel pairs, each pair presenting a vowel initiated abruptly and the same vowel initiated gradually. Each of the nine vowels and each of the five voices were presented several times in the two tapes combined.

After this preparation, the listeners judged each of 108 isolated vowels by indicating whether they did or did not hear abrupt initiation. The measure of abruptness of initiation was thus the number of listeners identifying abrupt initiation for each vowel.

The instrumentation for the listening session was a Concertone Model 1401 tape playback, a MacIntosh Model 50W2 amplifier and a Jensen BF409 multiple speaker system. Listening sessions were in a sound-treated room in two sessions on succeeding days.

## Results

*Scale Values.* The scale values of severity of harshness were abstracted from data obtained for another study (*15*). These scale values had been obtained by the method of equal-appearing intervals on a seven-point scale with *one* representing least severe harshness and *seven* representing most severe harshness. Satisfactory reliability had been established.

The measure employed as the scale value of abruptness of initiation was the number of listeners identifying abrupt initiation for each vowel. The median value, obtained in the manner described by Thurstone and Chave (*17*), for these measures was 19.5 and the *Q* value was 7.12. The range was from 1 to 32. Since abrupt initiation is a relative phenomenon, these measures were interpreted to mean that vowels receiving low scores were most gradually initiated while those receiving scores approaching 32 were most noticeably abruptly initiated.

The median agreement among listeners was 24.5 and the *Q* value was 3.60. On 82 (or 79%) of the vowels there was two-thirds or better agreement among the listeners. Conversely 26 (or 21%) of the vowels had

TABLE 1. Summary of analysis of variance for abruptness of initiation of isolated vowels.

| *Source* | *df* | *ms* | *F** | $F_{.05}$† |
|---|---|---|---|---|
| Vowels (V) | 8 | 245.98 | 7.77 | 2.05 |
| Speakers (S) | 11 | 365.17 | | |
| VS | 88 | 31.66 | | |
| Total | 107 | | | |

* $F = ms_V / ms_{VS}$

† $F_{.05}$ is the tabled value for the nearest given *df*.

TABLE 2. Differences among the mean number of 32 listeners identifying abrupt initiation of isolated vowels produced by 12 speakers with harsh voices. The critical difference (c.d.*) necessary for significance at the 5% level is 4.51.

| *Mean* | | *Vowels* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | [i] | [ɑ] | [ɔ] | [ɪ] | [ɛ] | [æ] | [ʊ] | [ʌ] |
| 9.33 | [u] | 2.75 | 9.09† | 9.75† | 9.74† | 10.59† | 10.75† | 11.09† | 14.67† |
| 12.08 | [i] | | 6.34† | 7.00† | 7.59† | 7.84† | 8.00† | 8.34† | 11.92† |
| 18.42 | [ɑ] | | | .66 | 1.25 | 1.50 | 1.66 | 2.00 | 5.58† |
| 19.08 | [ɔ] | | | | .59 | .84 | 1.00 | 1.34 | 4.92† |
| 19.67 | [ɪ] | | | | | .25 | .41 | .75 | 4.33 |
| 19.92 | [ɛ] | | | | | | .16 | .50 | 4.08 |
| 20.08 | [æ] | | | | | | | .34 | 3.92 |
| 20.42 | [ʊ] | | | | | | | | .58 |
| 24.00 | [ʌ] | | | | | | | | |

*c.d.$=t_{.05}(2\text{ms}_{\text{error}}/\text{n})^{1/2}$. See Table 1 for error term.
†Significant at the 5% level.

scores ranging from *12* to *20* indicating that these vowels were approaching individual listener's thresholds for noticeably abrupt initiation. Only two vowels received a score of *16*, indicating a split or threshold judgment.

*Results of Analysis.* The data from judgments of abruptness of initiation of the isolated vowels were analyzed by the technique of analysis of variance in a two-factor design, vowels-by-speakers. The criterion measure was the number of listeners out of a total of 32 identifying the presence of an abrupt initiation.

Abrupt initiation was more evident on some vowels than on others as shown by the significant result of the *F* test. A summary of the analysis appears in Table 1. The vowels [i] and [u] had significantly lower mean abruptness of initiation scores than the other vowels. Of the remaining vowels only [ɑ] and [ɔ] had significantly lower mean scores than [ʌ] which received the highest score. Differences between means for all possible pairs of vowels are shown in Table 2.

TABLE 3. Mean abruptness of initiation and mean severity of harshness ratings for isolated vowels for each speaker.

| *Speaker* | *Mean Abruptness of Initiation* | *Mean Severity of Harshness* |
|---|---|---|
| 1 | 18.44 | 2.87 |
| 2 | 15.11 | 3.04 |
| 3 | 22.44 | 3.48 |
| 4 | 2.78 | 3.91 |
| 5 | 21.56 | 4.40 |
| 6 | 14.11 | 3.45 |
| 7 | 19.00 | 4.89 |
| 8 | 19.33 | 4.50 |
| 9 | 17.33 | 4.48 |
| 10 | 29.00 | 5.56 |
| 11 | 23.11 | 4.92 |
| 12 | 15.11 | 3.18 |

A Pearson *r* was computed between abruptness of initiation scores and severity of harshness ratings for each vowel for the 12 speakers. The correlations were as follows: [u], .44; [i], .55; [ɑ], .47; [ɔ], .38; [ɪ], .26; [ɛ], .45; [æ], .58; [ʊ], .46; [ʌ], .08. The only

obtained $r$ significantly[1] greater than zero was the $r$ of .58 for the vowel [æ]. This vowel received a relatively high abruptness of initiation score and was one of the most severely harsh of the isolated vowels. The lowest obtained $r$ was .08 for the vowel [ʌ]. This vowel received the highest abruptness of initiation score and was rated as moderately harsh.

The means of the abruptness of initiation scores and of the severity of harshness scale values are shown for each speaker in Table 3. The correlation between these two sets of means, with the effect of vowels averaged, was .50 ($df$=10) which is not significantly greater than zero.

TABLE 4. Mean abruptness of initiation and mean severity of harshness ratings averaged over 12 speakers for each isolated vowel.

| *Vowels* | *Mean Abruptness of Initiation* | *Mean Severity of Harshness* |
|---|---|---|
| [u] | 9.33 | 3.65 |
| [i] | 12.08 | 3.80 |
| [ɑ] | 18.42 | 4.14 |
| [ɔ] | 19.08 | 4.36 |
| [ɪ] | 19.67 | 3.60 |
| [ɛ] | 19.92 | 4.40 |
| [æ] | 20.08 | 4.40 |
| [ʊ] | 20.42 | 4.01 |
| [ʌ] | 24.00 | 4.14 |

The mean of abruptness of initiation scores along with the mean severity of harshness ratings for each vowel is shown in Table 4. The correlation between these two sets of nine measures each, with the effect of speakers averaged, was .56, a correlation showing about the same strength of relationship for vowels as for speakers.

In summary, differences among vowels with respect to abruptness of initiation were significant. The vowels [i] and [u] had lower abruptness of initiation scores than the other vowels. The only other significant differences obtained were between [ʌ] with the highest score and [ɑ] and [ɔ]. On the basis of the obtained data, with an $N$ of only 12, there is no statistical evidence of more than a chance relationship between abruptness of initiation and severity of harshness of isolated vowels for any one of the individual vowels, except for [æ]. It should be noted, however, that all nine correlation coefficients for individual vowels were positive and that the coefficients for vowels averaged and for speakers averaged were also positive.

## Discussion

As pointed out in previous discussion, laryngeal tension has frequently been posited as a causal factor in the production of harsh voice quality. It was also pointed out that Moore's data indicated that there is a relationship between laryngeal tension and the glottal attack. It was thought, therefore, that tense vowels would be more likely to be abruptly initiated than lax vowels. The tense vowels [i] and [u] received lower abruptness of initiation scores than the other vowels. The other tense vowel [ɔ] was significantly different from [i] and [u] in this respect and could not be differentiated from any of the lax vowels on the basis of this measure except for [ʌ] which received the highest score. While no clear-cut con-

[1] $r_{.05}\ (df = 10) = .576$

clusion may be drawn from these data, the lax vowels were, in general, more abruptly initiated than most of the tense vowels. Apparently the tension associated with the vowel does not contribute to the tension present in abrupt vowel initiation. Possibly the undue tension associated with abrupt initiation interferes more with the vowels produced with relatively relaxed tongue musculature. Abruptness of initiation may be more closely related to the open-closed classification of vowels than to the tense-lax classification. Drew and Kellogg (*8*) reached the following conclusion from oscillographic study of vowels: 'The most sudden attack seems to be produced by building up some air pressure in the lungs with the epiglottis closed, and releasing this suddenly, which has the effect of beginning the sound with something like a grunt.' They found that abrupt starts with 'shoulder type' envelopes were somewhat more common in the open vowels. Accordingly, [i] and [u], since they are closed vowels, would be expected to show more gradual starts than the other vowels. Perceptually they were less abruptly initiated than other vowels.

On the basis of the data obtained for this study, there is little statistical evidence of a relationship between abruptness of vowel initiation and degree of perceived harshness. Correlations for these measures, with but one exception, were not significantly greater than zero. The *N*, however, was small, and all nine correlation coefficients were positive. Also the relationship was positive both for the average over speakers and for the average over vowels. These results thus can be interpreted as evidence to support the conclusion that there is some tendency for abrupt initiation to be associated with harshness in the general population of harsh voices.

The abrupt type of initiation was apparently present on many of the isolated vowels produced by the 12 harsh voices. Whether this group produced vowels with abrupt initiation more frequently than would non-harsh voices is not known. One or more vowels which a majority of the listeners agreed were abruptly initiated were produced by 11 of the 12 voices. Speaker 10, who produced the most severely harsh isolated vowels and who was ranked first in over-all severity of harshness, initiated all isolated vowels abruptly. The mean of abruptness of initiation scores for this speaker was 29.00. Speaker 4, who ranked seventh in the production of severely harsh isolated vowels but ranked fourth in over-all harshness on a longer series of syllables (*15*), produced no abruptly initiated vowels. The mean of abruptness of initiation measures for this speaker was 2.78. The means of these measures for the remaining speakers ranged from 14.11 to 23.11. Individual scores ranged from 1 to 32. These data support an earlier conclusion of Drew and Kellogg (*8*) that abrupt starts were probably an individual characteristic. They stated that such abrupt starts were not associated with any observable 'hardness of voice.'

## Summary

Isolated vowels produced by speakers with harsh voices were studied with respect to abruptness of initiation and its relationship to degree of perceived harshness. The vowels were [i], [ɪ], [ɛ], [æ], [ʌ], [ɑ], [ɔ], [ʊ] and [u].

Twelve speakers with clinically

diagnosed harsh voices recorded the vowels in an anechoic room using high-fidelity recording equipment. Each vowel was judged for the presence or absence of abrupt initiation by 32 listeners. Vowels were also rated for severity of harshness on a seven-point equal-appearing intervals scale.

On the basis of the obtained results the following statements concerning production of isolated vowels by harsh voices may be made: (a) The vowels [i] and [u] are less abruptly initiated than the other vowels. The vowels [ɑ] and [ɔ] are less abruptly initiated than [ʌ], which is most abruptly initiated. (b) Severity of harshness on [æ] tends to vary with abruptness of initiation. For the other vowels, evidence of correlation between severity of harshness and abruptness of initiation is non-conclusive.

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# Survey Of Hearing Losses Among Armor Personnel

Lawrence N. Solomon

John L. Fletcher

Technological changes in the Army have resulted in the development and increased use of more powerful vehicles and weapons on the company level. This, in turn, has resulted in an increase in the noise levels to which personnel are exposed, and a consequent increase in the risk of noise-induced hearing loss in personnel.

In view of the cost to the government of service-incurred hearing losses, which to a large measure could be prevented, it seemed advisable to make a survey of hearing losses among Fort Knox personnel and, if possible, to relate these losses to noise exposure. The survey group consisted of 3099 armor, armored artillery and armored infantry personnel.

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## Procedure

*Group Audiometry.* Group audiometry measures were obtained by means of the Recorded Warble Tone Hearing Test, fourth revision, developed by the U. S. Navy Electronics Laboratory (NEL). For a complete description of the NEL test and method of testing, see Webster (*8*).

Eighteen subjects were tested simultaneously by means of an earphone network, each ear being tested separately at each of the following frequencies: 500, 1000, 2000, 4000 and 7000 cps. The test measured hearing loss within a 48 db range, the results being slightly truncated due to the fact that negative hearing losses were not adequately covered in the limited range of the recorded test.

*Determination of Noise Exposure Scores.* A recent study (*1*) of ambient noise levels in armored vehicles (T-41, M-42, M-44, T-59, M-75, T-97 and T-98) reveals that crew members in these vehicles are working in an ambient noise environment of from 115 to 125 db. Measurements made by the present authors revealed that the noise level in the track vehicle maintenance shop is approximately 104 db. Additionally, certain men in the sample were exposed to gunfire intermittently where quantitative noise measurements were not possible.

On the basis of their responses on a hearing data questionnaire to questions relating to jobs held and length of time on each job, the personnel were divided into noise exposure groups. A semi-quantitative technique of combining job noise levels and length of time on job was devised to permit assigning subjects to one of three categories of noise exposure: negligible, moderate, and severe. The negligible group included individuals ordinarily exposed (during the work day) to noise levels up to 89 db, or who had been exposed to 90 to 99 db for less than 18 months, or 100 to 109 db for less than three months. The moderate category included those exposed to 90 to 99 db of noise for more than 18 months, or 100 to 109 db for less than 18 months, or over 110 db for less than three months. The severe group contained those exposed to 100 to 109 db for more than 18 months, or over 110 db for more than three months.

In order to compensate for the fact that estimations of noise exposure for survey populations tend to be very coarse, only the data from the negligibly and the severely exposed are discussed in this report.

*Testing Environment.* All testing was done in a sound-treated room with an ambient noise level averaging 54 db. An octave band analysis indi-

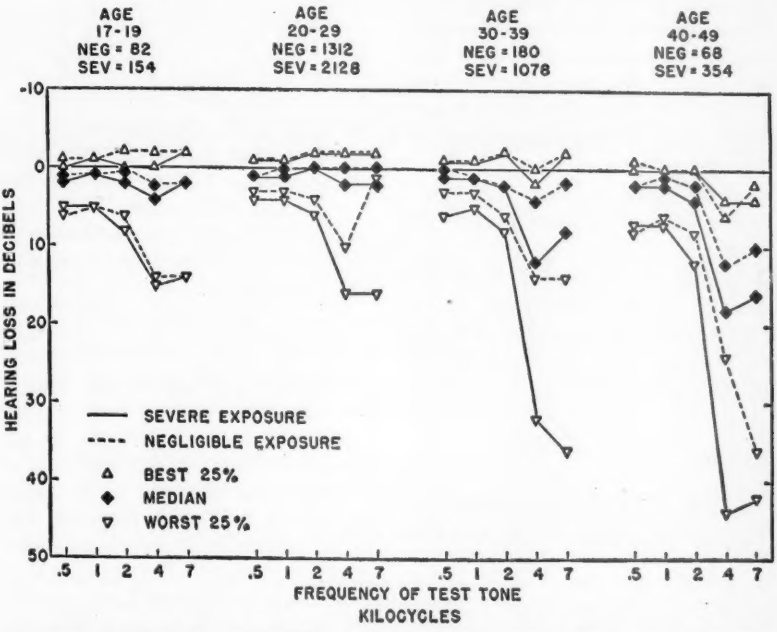


FIGURE 1. Hearing loss as a function of age and noise exposure. Note: Quartile value of 44 db hearing loss represents a minimum estimate. The testing procedure did not allow determination of hearing loss values greater than this at 4 and 7 kc.

cated that masking due to ambient noise should not be expected for the test tone frequencies used in this study, except for slightly more than one db of masking at 500 cps (*4*).

## Treatment of Data

The data were processed on IBM cards and tabulated to determine the hearing loss of the poorest 25%, the median, and the best 25% of ears for each of the four age categories and for each of two noise exposure groups, negligibly exposed and severely exposed.

The hearing loss baseline for the population was established by selecting ears of persons in the age range of 20 to 29 years, who had negligible noise exposure and who had negative medical histories.[1] The median hearing loss for this group was then used as the reference point for all hearing losses, and this loss defined the 'zero hearing loss' for this study. Use of this 'biological baseline' technique is well established in hearing survey research (*6*, 7, *9*).

Whenever differences in hearing loss are termed 'significant' in this report, reference is made to statistical significance only, as tested by the paired-replicates test (*11*).

## Results

*Hearing Loss as a Function of Age.* The age distribution of the 3099 subjects tested with the NEL group hearing test ranged from 17 to 49 years of age. The median age of the group was 25 years. Hearing losses for the different age groups are shown in Figure 1. Exclusion of the moderately exposed subjects eliminated 842 ears from the sample, leaving the number of severely and negligibly exposed ears in each age range indicated in Figure 1. The data plotted in Figure 1, therefore, are based upon results from 1642 negligibly exposed ears and 3714 severely exposed ears.

It is evident from Figure 1 that, for ages above 20 years, hearing losses increased with age. On the other hand, the data show that the 17- to 19-year group had greater hearing loss than the 20- to 29-year group. Steinberg *et al.* (*6*) also found their youngest age group (10 to 19 years) had slightly poorer hearing than that of the next older group (20 to 29 years) and believed that this phenomenon was due to the greater difficulty experienced by the younger persons in understanding the test instructions. This explanation would not appear to be as applicable for the 17- to 19-year group in the present study.

*Hearing Loss as a Function of Noise Exposure.* Figure 1 also presents a graphical comparison of the hearing losses of the negligibly and severely exposed subjects of each of the age groups included in this study. For Figure 1, the following point should be kept in mind regarding the data obtained from personnel in the oldest age group: selective factors other than noise exposure, such as Army personnel policies, may have served to screen out individuals more typical of the general population of hearers.

[1]It was not uncommon to find subjects who had had medical treatment for one ear, but whose other ear showed no positive medical history. In such a case, the 'good' ear was included among the normative data.

The differences in hearing loss between the negligibly and severely exposed in the two youngest groups (17 to 19 years and 20 to 29 years) are small, but generally in the expected direction. Hearing loss differences between the negligible and severe exposure cases grow increasingly larger as the age of the subjects increases, especially at the higher frequencies. This result is subject to at least two interpretations: (1) younger ears are more resistant to noise induced loss; or, (2) the cumulative effects of noise exposure result in older persons suffering more loss. Both of the above hypotheses could be correct, with each of these factors contributing to the data simultaneously.

Figure 1 also shows that the poorest 25% of the severely exposed older subjects have greater hearing losses, proportionally, than the poorest 25% of the negligibly exposed older subjects, especially at 4000 and 7000 cps. The best 25%, however, do not differ significantly at any age level. This seems to imply that of the ears exposed to high level noises, about one fourth are relatively unaffected, another fourth incur relatively large losses, and the middle half show small but measurable hearing losses.

*Comparison to Other Survey Data.* Pulse Tone Type Recorded Tests. Table 1 presents central tendency measurements from the Fort Knox (FK), the San Diego Fair (SDF) (7), and the World's Fair (WF) (6) hearing loss data for the different age groups and for the five test tone frequencies used. The differences within any given frequency-age group between FK data (based upon negligibly, moderately, and severely exposed individuals combined) and the

TABLE 1. Average hearing losses, in db, for San Diego Fair (SDF), World's Fair (WF), and Fort Knox (FK) data.

| *Age* | *N** | *Test Group* | *Frequency of Test Tone†* 440 | 880 | 1760 | 3520 | 7040 |
|---|---|---|---|---|---|---|---|
| | 415 | SDF | −1.3 | −0.7 | 0.4 | 3.8 | 3.9 |
| 20-29 | 3287 | WF | 0.0 | −0.2 | −0.1 | 2.0 | 1.5 |
| | 2088 | FK | 1.0 | 0.0 | 0.0 | 2.0 | 2.0 |
| | 383 | SDF | 0.3 | 1.3 | 2.2 | 7.7 | 6.5 |
| 30-39 | 3197 | WF | 1.4 | 1.3 | 2.3 | 8.2 | 7.7 |
| | 699 | FK | 1.0 | 1.0 | 2.0 | 10.0 | 6.0 |
| | 271 | SDF | 1.3 | 2.4 | 6.0 | 13.2 | 13.3 |
| 40-49 | 4528 | WF | 3.7 | 4.5 | 7.0 | 17.7 | 16.8 |
| | 231 | FK | 1.0 | 2.0 | 4.0 | 16.0 | 14.0 |

*N for all three test groups is given in terms of people, rather than ears. However, at SDF the signal came to both ears simultaneously; so hearing loss represents the function of the better ear. At WF the subjects held the earphone with one hand and wrote with the other; so hearing loss was measured only in the ear opposite to the person's handedness; at FK each subject's ears were tested separately.

†Frequencies for the FK data were 500, 1000, 2000, 4000 and 7000 cps.

SDF and WF data were tested by the paired replicates tests and were found not to be statistically significant.

Group *Versus* Individual Clinical Audiometer Tests. Differences do appear, however, between the data of this survey and comparable data from certain other surveys. Figure 2 pre-

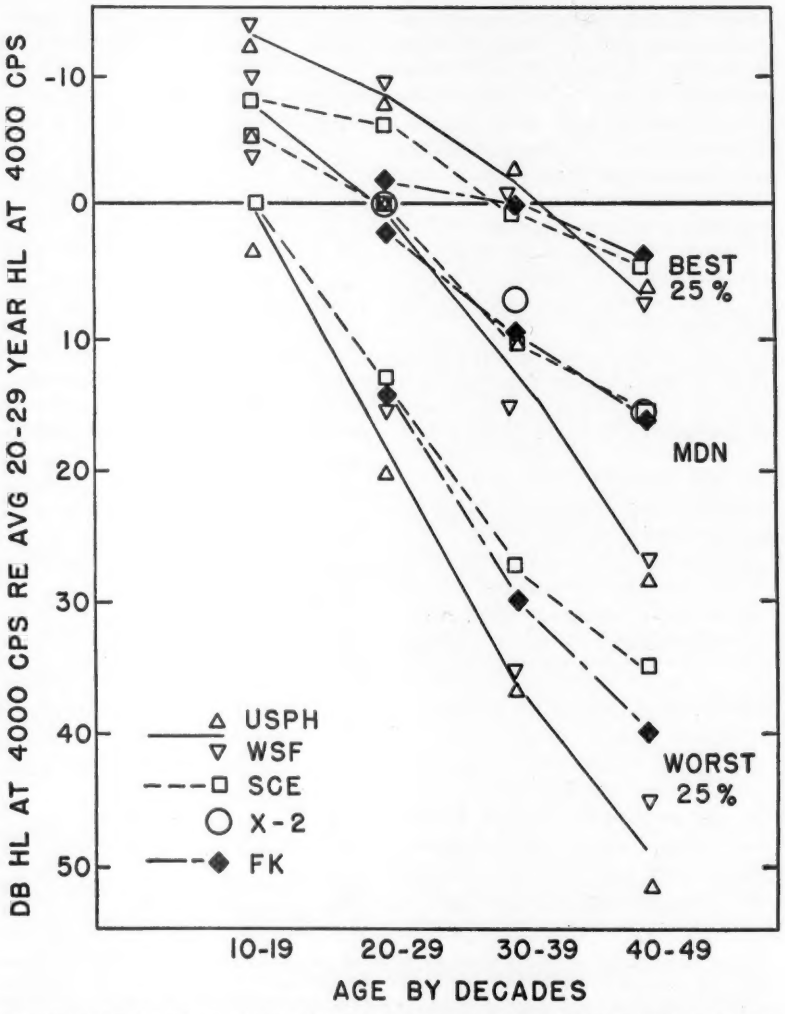


FIGURE 2. Hearing loss at 4000 cps from the U. S. Public Health Service, Wisconsin State Fair, Southern California Exposition, X-2, and Fort Knox data relative to the average loss at 4000 cps for the 20- to 29-year group.

sents the hearing loss at 4000 cps for U. S. Public Health (*5*), Wisconsin State Fair (*3*), Southern California Exposition (*10*), American Standards Association Committee X-2 (*2*), and Fort Knox data relative to the average loss at 4000 cps for the 20- to 29-year group. It will be seen that the X-2,

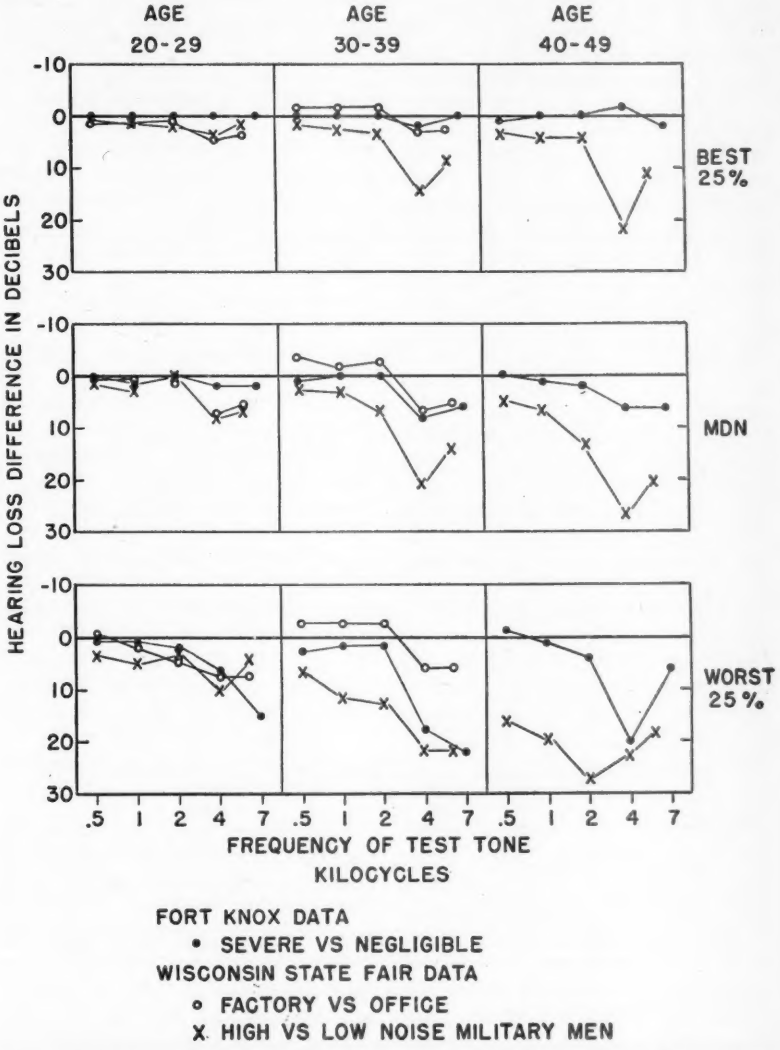


FIGURE 3. Differences between hearing losses of noise exposed and non-noise exposed men.

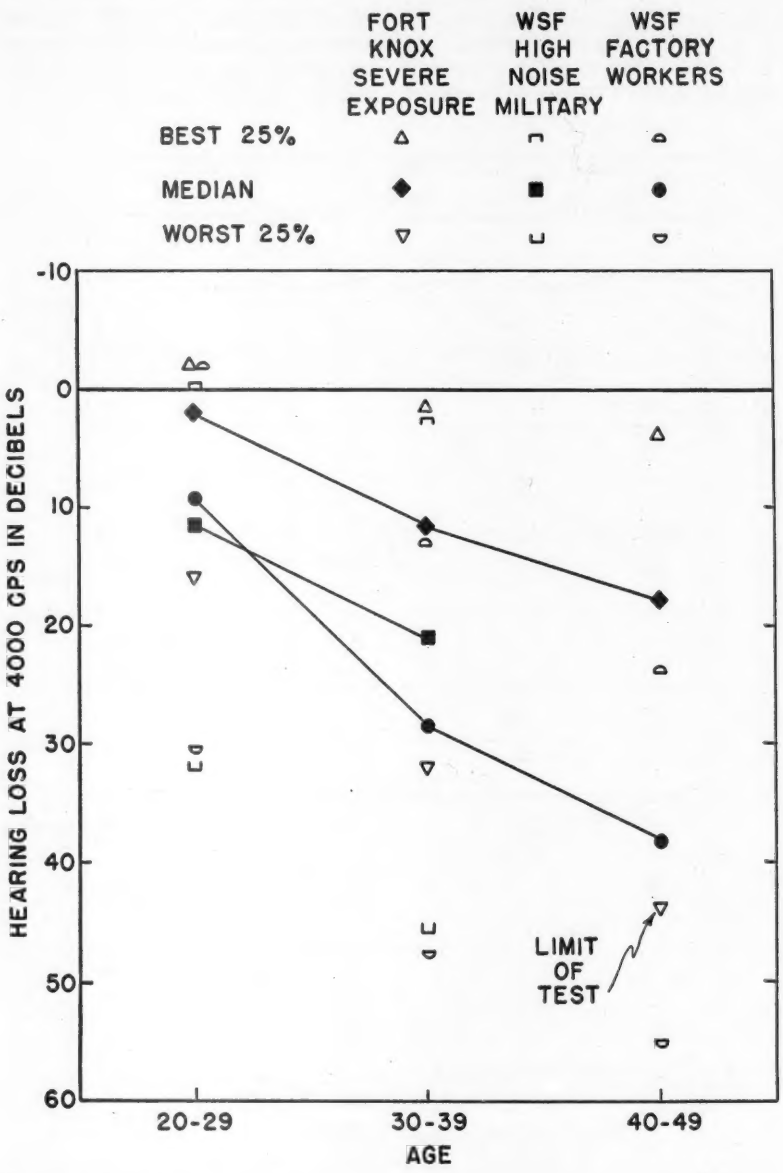


FIGURE 4. Hearing loss at 4000 cps for three groups of noise exposed subjects (WSF data corrected 10.4 db to 'biological baseline').

SCE, and FK data agree quite well, while the USPH and WSF data generally show greater losses at all ages (except for the best 25% of the hearers). This finding is not unexpected, since the X-2, SCE and FK data are based upon results from group tests. The USPH and WSF data are derived from measurements collected on an individual basis using a clinical pure tone audiometer and the corresponding psychophysical method. The range of hearing losses measured on a clinical audiometer is roughly double that of any recorded group test. The truncated distributions resulting from the restricted range of the group test may be sufficient to account for the differences apparent in Figure 2.

Noise *Versus* Non-noise Exposed Ears. Figure 3 presents a graphic comparison of the differences in hearing loss between severely *versus* negligibly exposed subjects in the FK study; factory *versus* office workers in the WSF data; and high *versus* low noise exposed military men also from the WSF study. Inspection of this figure reveals that within the 20- to 29-year age range there are only slight differences between each of these three sets of data. With the exception of the poorest hearing quartile, greater differences are shown in the two WSF comparisons than in the FK comparison.

In the 30- to 39-year age range, for the best 25% and the median groups, the differences between severely and negligibly exposed armor personnel and between the high and low noise military men are about the same, while differences between factory workers and office workers are substantially greater. Among the worst 25% of the hearers at this age, high noise and low noise military men differ very little in hearing loss, while the differences between severely and negligibly exposed FK subjects and between factory and office workers are much larger at all frequencies tested, especially so at the higher frequencies.

In the 40- to 49-year age range, no data were available from the WSF study on high *versus* low noise military men. The factory workers in all quartiles and at all frequencies show markedly greater hearing losses than office workers. This difference between noise and non-noise exposed subjects becomes apparent in the FK data with the median groups and is most apparent, although not as great as in the WSF groups, among the worst 25% of the hearers.

In order to clarify further the comparison between the WSF data and the FK data, hearing losses at 4000 cps were plotted in Figure 4, with the WSF data replotted using a biological baseline; that is, the hearing loss of their 20- to 29-year group who were comparable to the normative group of the present study was arbitrarily called zero hearing loss. It was found that this group had a median hearing loss of 10.4 db at 4000 cps; therefore, this value was subtracted from the hearing loss values of the high noise military men and the factory workers and was plotted in Figure 4.

It may be seen from inspection of Figure 4 that the severely exposed FK subjects exhibit less hearing loss in all quartiles than do the WSF subjects. Some of this difference, of course, may be due to differences between group test results (FK) and individual test results (WSF), as is evident in the 40- to 49-year group score for the FK data in the worst 25% of hearers. Here, the limit of the test was reached, so that a hearing loss of 44 db merely represents the maximum hearing loss

value that could be obtained. At other points, however, where the limit of the test was not reached, this explanation would not hold.

## Summary

The hearing of 3099 armor, armored artillery and armored infantry personnel was tested by means of a group audiometer test. On the basis of information from a hearing data questionnaire, the subjects' hearing losses were related to age and previous noise exposure.

Generally, hearing losses were found to increase with age, particularly hearing losses at the higher frequencies. Median hearing loss differences between negligibly and severely exposed individuals ranged from no difference to moderate difference depending on frequency and age group. The differences tended to be greater for the poorest 25% of the two groups, especially for the older age ranges.

The results of this survey were compared with the results obtained from previous surveys and analyzed in terms of group *versus* individual audiometer tests and noise *versus* non-noise exposed ears. It was found that the present results agree quite well with other surveys utilizing a group testing procedure. However, the hearing loss differences between noise exposed and non-noise exposed subjects in this study were not as great as have been found in other surveys of similarly exposed individuals.

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# Functional Speech Disorders And Personality: A Survey Of The Research

Leonard D. Goodstein

Clinical case reports in speech pathology are almost always concerned with the personality of the speech-handicapped individual as an important factor in formulating the etiology of the problem and in evaluating the assets of the person for therapeutic planning. Since speech-handicapped individuals seen by speech pathologists are frequently children under the influence of their parents, the personality of the parents becomes a matter of interest as an etiological factor in the development of the disorder and in the utilization of the parents as therapeutic agents. Yet despite the importance placed upon the personality and adjustment of speech-handicapped individuals and their parents in both diagnostic and therapeutic work, the research evidence relating pathology of speech and personality is widely scattered and there have been few attempts at any systematic survey of this evidence. Furthermore much of this evidence is difficult for those speech pathologists without considerable formal training in psychometrics, particularly personality measurement, to evaluate and utilize. This paper is an attempt to summarize and evaluate those investigations in which the personality and adjustment of individuals with functional speech disorders and their parents were measured and some comparison with a control group was made.

The present paper is based upon a survey of the literature of the past 25 years (through December, 1957) abstracted in the *Journal of Speech and Hearing Disorders*, the *Psychological Abstracts* and the *Speech Monographs*. Included are all studies of an investigative nature reporting on the relationship between functional speech problems and measured personality and adjustment. Not included are those studies dealing with organic speech disorders, with disorders of hearing,[1] with disorders of speech resulting from severe psychopathology, with stage fright or with the relationship between expressive speech and personality in normal persons.

The scope of this paper is further limited by the exclusion of those reports which are essentially clinical case studies in which some relationship between a functional pathology of speech and some aspect of the patient's personality or adjustment is reported. The published literature in speech pathology, psychiatry and psychology is replete with such clinical papers reporting that the author has a number of patients, typically a small number, and in each case it was

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[1]See (*9*) for an excellent summary of this literature.

'immediately obvious' that the pathology of speech was definitely related to some etiological condition, such as an Oedipus complex or an acute state of anxiety. Perhaps one example might serve to illuminate this point: Stein (*96*) reported from his experience with a 'small number of male stammering cases seen in the Tavistock Clinic . . . (that) in the background of more than half the cases studied we find the male stammerer identifying himself with the mother in the presence of a monstrous, violent, overpowering father. Homosexuality of an infantile narcissistic kind, usually strongly suppressed, is a frequent phenomenon.' It should be clear that such reports, regardless of the author's clinical acumen or sagacity, can scarcely be considered as meeting the usual methodological criteria in scientific inquiry. Further, since typically these personality factors can be uncovered only by specially trained psychiatrists or clinical psychologists, such findings are of little practical use for most speech pathologists.

Excluded also, because of limitations of space, were those studies in which the major concern was an evaluation of the reactions to a functional speech disorder, for example, the reactions of stutterers to their impediment. Also excluded from this report are those theoretical papers in which the need for personality research was stressed, although no actual research data were included. Speech pathologists are all too frequently exhorted to study personality, develop more and better clinical skills in this area, use the Rorschach and other personality tests; but all of this without any direct suggestions or, even more importantly, without any evidence as to how this can be realistically done in typical clinical practice. The present report includes only those investigations in which some empirical relationships have been reported between personality variables and the major functional disorders of speech: articulation disorders, delayed speech, voice disorders and stuttering.[2]

## Articulation Disorders

Functional disorders of articulation —the omission, substitution or distortion of speech sounds—are typically explained (*49*) in terms of a disruption of the normal learning process in speech development. Such disruption may be a function of inadequate speech models, of a lack of stimulation in and motivation for adequate speech, or of some more basic emotional disturbance. Since such etiological factors are seen as operating in the home environment in the typical developmental sequence, the area of parent-child interactions must be investigated.

*Personality and Adjustment of the Parents.* The study by Wood (*103, 104*) is the only systematic investigation of the relationship between parental adjustment and the presence of functional articulatory defects in children. Wood's study involved the parents of 50 children whose articulatory speech defects were not assignable to low intelligence, hearing loss or any organic malformation. The

[2]Five studies (*26, 31, 85, 97, 105*) were not included because the authors studied heterogeneous groups of speech-defective individuals without further specifying the composition of the group. Such investigations may obscure significant differences within the group, producing results that may be misinterpreted.

parents were likewise found to be normal in intelligence, hearing and speech. Data concerning environmental factors and emotional adjustments of both children and parents were obtained by means of psychological tests,[3] including the adult form of the California Test of Personality (CTP), the Bernreuter Personality Inventory and the Thematic Apperception Test (TAT). Parental adjustment, as measured by the scores on the personality tests (when compared with the test norms), indicated considerable emotional maladjustment of one or both parents, with more maladjustment found for the mothers than for the fathers. The case histories revealed disruptions in the home, including both parents working, both parents away from home frequently or the parents separated or divorced. The data also showed that these parents had few interests outside of the home, that they were ignorant of good child-rearing practices and used overly severe techniques of child discipline. It is unfortunate that this important study did not utilize an adequate control group for purposes of comparison.

One of the most significant aspects of this study, to some extent obviating this criticism, was that the 50 cases were then divided into two matched groups for a program of therapeutic procedures. For one group of 25 children, ordinary remedial articulation procedures were followed; for the other 25, extensive parental counseling was carried on in addition to the speech training. Children of this second group were found to improve more rapidly in their speech than did those whose mothers were untreated. Wood concluded that parental emotional factors are important not only in the etiology of articulation defects but also in any corrective treatment.

Lerea (*55*) reported, however, that there was no relationship between the rated severity of children's articulation disorders ($N=28$) and the personality of the mother as measured by the CTP, but these children all had speech problems as a function of some physical disorder. Further support of Wood's conclusions is found, however, in the results of Egbert (*30*) who compared 31 pairs of children with articulatory disorders, one group with superior progress in speech therapy and the other group with below average progress. These pairs were matched as to sex, scholastic achievement, age, IQ, severity of disorder and therapist. Using data obtained in clinical interviews, Egbert found significant differences between the mothers of the two groups. The mothers of the successful group had more information about speech therapy and were more active as auxiliary therapists than the mothers of the below-average progress group. On the other hand, the mothers of the below-average progress group were reported to use frequent and injudicious punishment and, more frequently than the mothers of the successful group, to use undesirable methods of speech retraining.

*Personality and Adjustment of the Children.* There is more research dealing with the child with articulatory disorders and his personality and adjustment. Twelve studies, including

[3] It is beyond the scope of the present paper to discuss either the basic issues involved in personality measurement or the typical instruments utilized in such measurement. The interested reader will find the recent volumes by Allen (*2*) and Ferguson (*33*) useful introductions to this problem.

Wood's child data, are concerned with this problem: five of these studies report findings that are interpreted as indicating these children do have personality and adjustment problems; four studies report no relationship between personality or adjustment and the disorder; three studies have internally contradictory results.

Of the five studies reporting a positive relationship between functional articulation disorders and personality, Deming (*23*), using the Bender Visual Motor Gestalt Test ($N$=20); Greenberg (*42*), using the Rosenzweig Picture Frustration Test and the Brown Personality Inventory ($N$=36); Kennedy (*50*), using the personality rating scale of the American Council of Education ($N$=27); and Bjermeland (*12*), using the Thematic Apperception Test (TAT) ($N$=21) – all reported emotional disturbances in their speech-defective subjects. Perrin (*73*) obtained sociometric ratings on a large group of elementary school children, 9% of whom were receiving speech therapy, the majority of them ($N$=37) having functionally defective articulation. Perrin reported that more of the isolates came from the speech-defective group, that there were no leaders selected from this group and that the speech-defective child is not readily accepted into the classroom group.

All four of the studies reporting no relationship between personality and articulation disorders in children, Anders (*3*), McKee (*61*), McAllister (*58*) and Reid (77), have used the children's form of the CTP and reported no significant difference in test scores between groups of speech defective children and control groups. The number of cases in each of the groups was 53, 100, 100 and 38, respectively. Reid further reported no significant relationship between the test scores and either the original severity of the disorder or the amount of improvement following therapy.

The three studies with internally contradictory results have used two or more personality indices and have not found consistent results with the several measures. Both Wood (*103*, *104*) and Nelson (*70*) reported no relationship between articulation defects and personality as measured by the CTP. However, Wood interpreted his TAT results as indicative of personality disturbance, while Nelson ($N$=35) reported that his *Ss* received ratings by their classroom teachers of inferior adjustment on the Haggerty-Olson-Wickman Behavior Rating Scales. In a quite provocative study using sociometric ratings, Freeman and Sonnega (*37*) reported that articulatory defective children ($N$=26) are chosen less often by their peers for tasks requiring verbal speech, but that there was no difference in selection when the basis for choice was predominantly friendship.

*Evaluation of the Studies with Articulatory Disorders.* Any generalization about these studies as a whole is rather difficult in view of the inconsistent nature of the reported results. There does appear to be some evidence indicating the etiological and therapeutic importance of parental personality, but the need for better controlled, cross-validated studies using more valid indices of personality is nevertheless obvious. This need is even more obvious when the results with the articulatory-disordered children themselves are studied; Spriestersbach (*94*), in his recent review of some of this literature, reached much the same conclusion. These studies

generally tend to be poorly controlled, to be based on small *N*s (the median *N* was only 36) and to use poorly standardized and unvalidated personality measures such as the Bender Visual Motor Gestalt Test (*23*) and the Rosenzweig P-F Test (*42*). In evaluating the CTP, which was used in six of these studies, Allen (2, p. 100) concluded that the evidence was 'generally unfavorable with regard to the validity and reliability of the CTP' and urged care in the clinical interpretation of this test.

At present the only possible conclusion is that the relationship between personality factors and articulation disorders has not been clearly demonstrated and much additional research is required.

## Delayed Speech

Many cases of retarded speech development are referred to speech therapists when the retardation is not directly related to general mental retardation, to impairment of hearing, to motor defects or to anomolies of the speech mechanism. Explanations of such disturbances often stress the importance of parental influence and personality (*49*, *59*), and presumably research on parent-child interactions should provide clues about the etiological bases of this disorder and should also provide information useful in planning therapeutic work with these children.

The surveyed literature contained only two studies dealing with the personality factors involved in psychogenically delayed speech. Beckey (*5*), as part of a detailed clinical study of many factors related to retardation, compared 50 families with speech-retarded children with 50 families with normally speaking children. In so far as personality factors were involved (and these were ascertained from interviews and direct observations by the experimenter) the retarded children had their needs anticipated by their mothers without verbal request, and the parents, especially the mothers, regarded their children with more anxiety than did the normal children's parents. In a much more comprehensive study, Peckarsky (*71*) compared the attitudes of a group of 52 mothers of speech-retarded children with a matched control group by means of a psychiatric interview which was then evaluated according to the Fels Parental Behavior Rating Scales. The mothers of the speech-retarded group were rated as over-protective, rigid individuals who outwardly seemed devoted to their children but were actually very critical of them. The home environment of the delayed-speech children was characterized by rejection, tension and lack of organization in the performance of routine tasks. The attitudes of the control parents were less intense and pervasive, suggesting that the parents of the delayed-speech group were not different from the control parents in kind but merely in degree.

While these studies are intriguing and suggestive, it seems clear that much additional work needs to be done on the relationship between delayed speech and personality variables, particularly parental personality variables, as factors in therapeutic planning. No research has been reported on personality and the child without speech, but since the problem of psychogenically-delayed speech typically disappears before an age when adequate measures for personality and adjustment are available, this finding should not be surprising.

## Voice Disorders

Functional voice disorders, characterized by marked deviations in loudness, pitch, quality or flexibility, are also frequently explained as a result of psychological disturbance or maladjustment (*49*). Voice disorders, in contrast to both articulatory disorders and delayed speech, are frequently found in both adolescents and adults. Since good voice quality is an important factor in communication and, consequently, in adjustment, as Sanford (*80*) states in a discussion of this relationship, there should be a clearly established relationship between voice disorders and personality factors. Further it may be presumed that personality factors would play an important role in effective therapy with such disorders.

Considering the importance placed upon personality factors in voice disorders, it is surprising to find only three studies dealing with this problem. Moore (*68*) compared 119 college students with voice disorders with 43 college-level superior speakers on the Bernreuter Personality Inventory and reported that the whiney and breathy speakers ($N=61$) were significantly more submissive and emotionally unstable than the harsh and metallic speakers who were not different from the superior speakers. Duncan (27) reported that 10 out of 22 clinically-treated cases of functional hoarseness received scores indicating home maladjustment on the Bell Adjustment Inventory and that seven of the 10 hoarseness cases were in the group diagnosed as having an extreme degree of hoarseness. In contrast, only three of the 22 normal speakers in the matched control group received unsatisfactory scores on home adjustment. In the third study, Brice (*15*) obtained the TAT responses of eight college cases with severe voice disorders and concluded that her TAT measures of anxiety were inversely related to her independent, voice-quality ratings.

Despite the results of the above studies, the relationship between voice disorders and personality is yet to be empirically demonstrated. It must be noted that these studies have used personality measures of somewhat dubious validity; for example, Ferguson (*33*, p. 233) concluded that 'the validity of the (Bell) Adjustment Inventory has in no way been substantially demonstrated.' Further, the number of cases involved is very small, not one of these findings has been cross-validated, the adequacy of the control groups used is open to question and one of the investigators concluded a positive relationship despite the fact that the results did not meet her own limits of statistical significance. Again it should be clear that much additional research is required and that little is known about personality as an etiological, consequential or therapeutic factor in the disorders of voice.

## Stuttering

Of all of the functional pathologies of speech, none has excited more speculation or research than the phenomenon of stuttering, the severely hesitant, stumbling attempt at speech with spasmodic repetitions and pauses. Stuttering is often explained (*49*, *96*) in terms of psychological or personality factors either in the stutterer himself or in his background. Even those theorists who believe in the importance of organic factors will fre-

quently also include psychological factors in their formulations of the etiology of stuttering. Certainly there is no one concerned about the problem of the stutterer who denies the importance of stuttering as a factor in the consequent development of personality and adjustment or as a factor in therapeutic planning.

The severity and frequently bizarre nature of the stutterer's deviant speech behavior seemingly have led many to the extreme formulation that stuttering either is essentially neurotic or is a symptom of some underlying personality disturbance; for example (*24*), stuttering '. . . is only one aspect of the neurotic personality and there are always other neurotic traits present.' Bender (*6, 8*), as a demonstration of how widely such beliefs were held, asked 50 authorities in speech pathology to list the most common personal characteristics of stutterers. Most frequently reported as the most common were inferiority feelings (listed by 13 of the experts), self-consciousness (listed by 12), neuroticism (listed by nine), shyness and introversion (each listed by eight of these experts) and anxiety (listed by six). Bender himself (*6*) stated that stutterers are insecure, have extremely strong needs for affection and are inadequately socialized.

*Personality and Adjustment of the Parents.* Since all theories of stuttering, excluding those based exclusively upon organic factors, are essentially acquisitional or environmental theories (this would be true even for those theories which regard stuttering as neurotic in origin), and since the parental influence is most pervasive prior to and during the years of the onset of stuttering, studies of the stutterer's parents and the home environment should cast much light on the development of the stuttering phenomenon. Three such studies have attempted to assess parental attitudes through standardized clinical interviews which were then compared with the results obtained from a matched control group of parents. Moncur (*65, 66*) concluded on the basis of his results ($N$=48 in each group) that the stutterers' parents introduced adverse environmental influences into such parent-child interactions as eating, sleeping and toilet training. These parents were reported to have exceptionally high standards, to be overprotective, overcritical and particularly overdominant – attitudes which Moncur concluded precipitated and aggravated the stuttering. Johnson (*47, 48*) reported his two groups of parents ($N$=46 in each group) were very similar with only minor differences between them; these differences mainly centered around the stutterer's parents' concern about the adequacy of the child's speech. Darley's (*22*) results ($N$=50 in each group) tended to confirm those of Johnson in that he reported few striking differences between the two groups of parents. The stutterers' parents were less well satisfied with themselves and their children and had somewhat higher standards than the nonstutterers' parents although both groups appeared well within the normal range of adjustment. Darley further reported no significant differences between the two groups of parents on the Guilford Inventory of Factors STDCR.

Abbott (*1*) has reported a study involving direct observation of the behavior of mother and child in a free-play situation. Of the total $N$ of 60 mother-child pairs, half involved a

stuttering child. Although few of the differences between the two groups were statistically significant, Abbott concluded that the trends suggested overprotection by the stutterers' mothers, characterized by overt affection and seeming empathy in the play activity. Abbott further reported that on the Parent Attitude Research Instrument (PARI), which was taken also by the mothers, this tendency toward overprotection was again observable.

Three studies have been made to investigate the personality and adjustment of stutterers' parents by responses to the Minnesota Multiphasic Personality Inventory (MMPI), an empirically-derived paper-and-pencil inventory. Goodstein and Dahlstrom (*40*) found no significant differences on the MMPI between the parents of young, non-chronic stutterers and a matched control group ($N$=100 in each group). Goodstein (*39*) has cross-validated these findings with the parents of a typical group ($N$=50) of clinic stutterers. Grossman (*43*) reported only one significant difference on the 12 MMPI scales she used in her study ($N$=42 in each group) and further reported that, on the Minnesota Scale of Parents' Opinion, the stutterers' parents showed a marked inability to interpret the desirability or undesirability of specific child behavior traits and their influence upon the child's social and emotional adjustment.

LaFollette (*54*) compared a group of parents of stutterers with a matched control group of parents ($N$=85 and 50, respectively) on a battery of five paper-and-pencil personality tests and concluded that the fathers of stutterers were significantly more submissive than the fathers of the control group and, probably more importantly, were more submissive than their wives. The control-group parents did not show this difference. Wilson (*101*) and Christensen (*20*) both attempted to study the personalities of the same 30 stuttering children, of their parents, and of 30 nonstuttering siblings by means of three projective tests, including the TAT and the Rorschach. It was concluded that the stutterers were identified more closely with their mothers than were the nonstuttering siblings and that both the mothers and fathers seemed emotionally immature. Not all the conclusions were based upon statistically significant results and, more importantly, no really satisfactory control group was employed.

In summary, these studies of parental adjustment of stutterers suggest that there are differences between the parents of stutterers and nonstutterers, particularly in the parent-child interaction. These differences are not very suggestive of any gross maladjustment of the parents, but rather tend to center around subtle attitudes of perfectionism or criticalness, and there is some evidence that these attitudes are specifically related to the speech area. There was no evidence in these studies that would support the contention that the parents of stuttering children are severely maladjusted or have a particularly aberrant personality pattern. One important aspect of this problem, the relationship of parental personality to therapy with the child, has not yet been examined by research.

*Personality and Adjustment of the Child Stutterer.* Considerable research has been reported on the personality and adjustment of both the child and the adult stutterer. Using stuttering

children as subjects, Darley (*22*) found no significant differences on the Rogers Test of Personality Adjustment between the stutterers ($N$=28) and a matched control group ($N$=18), while Burleson (*18*) reported that no differences in personality were revealed by the Bender Visual-Motor Gestalt Test ($N$=36 in each group). McDowell (*60*) reported no significant differences between 46 pairs of stuttering and nonstuttering children on three personality tests, the Woodworth-Matthews, the Woodworth-Cady and the Kent-Rosanoff Free Association Test. Moncur (*67*) questioned the mothers of 42 stuttering children in a clinical interview and compared their responses with those of mothers in a matched control group. He concluded that the interview data as well as direct observation of the children themselves revealed that the child stutterers showed more symptoms of nervousness and maladjustment than did the child nonstutterers.

The Rorschach Test has been utilized by a number of investigators to measure the personality of the child stutterer. Meltzer (*62*) in an early study of stuttering children ($N$=64) concluded that the Rorschach responses were symptomatic of a neurotic disorder, but this study did not involve either statistical analysis or a control group. Meltzer (*63, 64*) in two later Rorschach studies involving a control group ($N$=50 in each group) concluded (*64*) that, although the stuttering children gave more responses, 'the nature of their responses reveals that their productivity represents compensatory and compulsive drives rather than clarity of perception or superiority in abstract thinking. . . . In practically all factors which imply emotional instability, the scores of the stuttering children exceed those of the control group.'

Wilson (*101*) and Christensen (*20*) used the Rorschach, the TAT and the Travis-Johnson Projective Test with 30 child stutterers, their nonstuttering siblings and the parents. In both cases the siblings were used as a control group and, while some differences in Rorschach responses were reported, neither of the findings was suggestive that the stutterers were more neurotic or maladjusted than their nonstuttering siblings.

Krugman (*53*) also used the Rorschach to assess the adjustment of a group of stuttering children, using a control group ($N$=50 in each group) of children with severe emotional problems. Although Krugman reported his stutterers gave fewer responses (in direct contradiction to Meltzer), he also concluded that both the stutterers and the problem children were predominantly unstable and neurotic, with the stutterers showing primarily obsessive-compulsive personality traits. It is noteworthy that diametrically opposite findings were used to reach the same conclusion; namely, that childhood stutterers are maladjusted with obsessive-compulsive personality traits. It would seem to the present writer that the adjustment of stuttering children as revealed by the Rorschach is still an open question.

The Krugman report was one of a series of studies which compared these same 50 stuttering and 50 problem children on a variety of performance measures (*19, 24, 52*). Kopp (*52*), reporting the performance on the Ozeretsky Tests of Motor Proficiency, concluded that the stutterers had a global uniform deficiency in motor functioning despite the fact that

there were no quantitative differences. In a recent cross-validation study (*35*), however, the stutterers were slightly, but not significantly, superior to a matched group of normal controls ($N=15$ in each group) and both groups were essentially average when compared to the test norms. There was no indication in this later study of the uniform deficiency in performance noted by Kopp, strongly suggesting the need for cross-validation in research of this type.

In general there is little evidence to support the contention that the stuttering child has a particular pattern of personality or is neurotic or severely maladjusted. This conclusion is supported by those studies of the educational achievement of stutterers (*29, 81*) which report only a slight educational retardation, approximately of six months, for stutterers. If stuttering children are as disturbed as some theorists maintain, this disturbance should presumably have shown some substantial effect in stutterers' school achievement as well as in their speech.

*Personality and Adjustment of the Adult Stutterer.* Stuttering is the only functional disorder of speech to afflict a significant number of adults. Since the personality and adjustment problems of adults, as well as the measurement techniques sometimes used to assess such problems, tend to be different from those of children, the adult stutterer deserves special attention.

The personality and adjustment of the adult stutterer have also frequently been assessed by means of the Rorschach. Haney (*44*), Ingebregtsen (*45*), and Pitrelli (*74*) all used the Rorschach and have generally concluded that the stutterers' responses were symptomatic of a neurotic disorder, although none of these three studies involved a control group. Haney's study also involved stutterers' responses to the TAT from which he inferred that stutterers are 'spatially disoriented, structurally confused' and have contradictory self-concepts. On the other hand, Richardson (*78, 79*) reported no important significant differences on either the Rorschach or the TAT between a group of 30 stutterers and a matched conrol group.

Diverse results with a variety of projective tests have been reported in the literature. Bloodstein (*13*), for example, reported no difference in obsessive-compulsive signs on the TAT between stutterers and nonstutterers ($N=15$ in each group). Goodstein, Martire and Spielberger (*41*), also using the TAT, reported no differences between stutterers and nonstutterers ($N=30$ in each group) on two different indices of motivation for achievement. Font (*36*) reported no significant differences between stutterers ($N=9$) and nonstutterers ($N=49$) on the Kent-Rosanoff Word Association Test, while Silverman (*91*) reported that the TAT revealed his Negro stutterers had more dominant mothers than his Negro nonstutterers ($N=10$ in each group). Wilson reported that his group of stutterers were like his group of maladjusted nonstutterers ($N=50$ in each group) in that both 'have in common a certain motor ineptness' (*102*, p. 134) as revealed by the Mira Myokinetic, the Bender Visual Motor Gestalt and the Figure Drawing Tests. Bernhardt (*11*) has reported that the frequency of stuttering in a group of 44 stutterers was significantly related

to those areas of psychosexual conflict revealed by the Blacky Test, while Madison and Norman (*56*) interpreted their Rosenzweig Picture-Frustration Test results, obtained with 25 stutterers, as supporting the psychoanalytic contention that stuttering is compulsive in nature with strong tendencies toward self-aggression. The importance of cross-validation was again strongly suggested by Quarrington (*76*) who, with a group of 30 stutterers, was unable to confirm the earlier findings of Madison and Norman. Unfortunately neither study utilized a control group but relied rather upon the published test norms, which may not have been completely appropriate.

These projective studies of stutterers are so inconsistent both internally and with each other that, based on these results, no generalizations about the personality of the adult stutterer are possible. It is clear that there is no general support for the notion that adult stutterers are severely maladjusted or even consistently different from anyone else. Sheehan (*87*), in his recent review of some of these same projective studies, has come to much the same conclusion.

Essentially the same conclusions can be drawn from those studies in which the personality and adjustment of the stutterers were investigated by means of the clinical interview. Glasner (*38*), in an uncontrolled, impressionistic, non-statistical study ($N=70$), concluded that stutterers show a long history of over protection and pampering and have over anxious, excessively perfectionistic parents. Whitman (*100*) reported that her uncontrolled interview data, obtained with 15 male stutterers, indicated strong conflict over sexual identification. Only if one is willing to ignore the possible importance of such factors as experimenter bias and the lack of statistical analyses and control groups, can one place much credence in these results.

Somewhat more promising are those studies which have reported that the Rorschach can be successfully used to predict the outcome of therapy with stutterers. Both Shames (*84*) and Sheehan (*86*, *88*) concluded that certain of the Rorschach variables were related to the outcome of therapy, but their results were not entirely consistent, their *N*s were rather small (27 and 35 respectively) and their statistics were not entirely conclusive. Their results do, however, suggest that this approach may indeed provide valuable information about the important therapy area, although more research is still necessary.

Paper-and-pencil tests also have been widely used as indices of the personality and adjustment of the adult stutterers. Johnson (*46*), in an early study, administered the Woodworth-House Mental Hygiene Inventory to a group of 50 stutterers and a group of 70 psychoneurotics. He concluded that the stutterers' responses were more like those of House's normal standardization group than those of the neurotics, although the stutterers did report significantly more problems than did the normals. In a quite similarly designed study, Spriestersbach (*93*) compared 50 stutterers, 183 normals and 20 hospitalized psychotics, all males, on the Word-Picture Test of Social Adjustment. Spriestersbach's conclusion, like that of Johnson, was that the stutterers resembled the normal males more than they did the psychiatric

patients, although there was some suggestion that the stutterers were mildly socially maladjusted.

Several investigators have found no differences between stutterers and nonstutterers on personality inventories. Bearss (*4*), using the Adams Personal Audit and the Potter Incomplete Sentences Blank; Berlinsky (*10*), using the Saslow Screening Test; and Brutten (*17*), using the Maslow Security Index – all reported no significant differences between a group of stutterers and a matched control group ($N$=23, 14 and 16 respectively). Brown and Hull (*16*) concluded that their 59 stutterers showed no 'generalized inferiority' on the Minnesota Personality Scale when compared with the test norms.

On the other hand, a number of inventory studies have reported evidence of serious maladjustment in stutterers. Bender (*6*, 7), using the Bernreuter Personality Inventory, reported that male college stutterers were more emotional and introverted, less dominant and confident than nonstutterers ($N$=249 in each group). These results led Bender to conclude there was a particular kind of stuttering personality and that stuttering is 'definitely associated with personality maladjustment.' Schultz (*82*) and Perkins (72), using the California Test of Personality, both reached much the same conclusion ($N$=20 and 75 respectively); neither of these investigators, however, used a control group but, rather, the published test norms. Duncan (*28*) reported that stutterers were more maladjusted at home than nonstutterers ($N$=62 in each group) as revealed by the scores on the Bell Adjustment Inventory. Morley and Berlinsky (*69*) reported significant changes in scores on the Bell Adjustment Inventory in the direction of better adjustment as indicating successful stuttering therapy ($N$=5). Considering the previously noted lack of validity of this instrument, its use as the sole criterion measure raises some serious doubt as to the validity of the study itself.

The importance of cross-validation can again be noted by comparing the reported results of Richardson (*78*, *79*) with those of Shames (*83*), both of whom used the Guilford inventory of Factors STDCR. Richardson reported that her stutterers were significantly more socially introverted, more depressed, and less happy-go-lucky, with significantly higher scores on Factors S, D and R, than her nonstutterers ($N$=30 in each group). Shames reported that none of these differences was observable in his group ($N$=53) and the only observable difference was that the stutterers showed more thinking introversion (Factor T). Unfortunately, however, Shames did not use a control group but, rather, the published test norms and this procedure makes interpretation of the discrepancy difficult.

There is a series of five investigations of the personality and adjustment of adult stutterers which deserves special attention. These investigations utilize the MMPI, the only one of the inventories used in research with speech-handicapped groups which was empirically derived and which has been shown to have more than face validity. Boland (*14*), Dahlstrom and Craven (*21*), Pizzat (*75*), Thomas (*98*) and Walnut (*99*) all have reported that the mean MMPI profile for their groups of stutterers ($N$=24, 100, 53, 29 and 38 respectively) was somewhat elevated as compared either with the test norms or with a matched control

group. However, the higher means for the stutterers were still well within the normal range of adjustment as defined by the MMPI norms. Dahlstrom and Craven compared college stutterers with normal speaking college freshmen, with psychiatric patients and with college students who had sought counseling help on their personal problems. The authors concluded that, while the stutterers did differ from the control students, they were not as severely disturbed as the psychiatric patients and most closely resembled the college students with other kinds of problems. This study further reported no significant relationship between the MMPI scores and the severity of stuttering.

Several investigators, rather than assessing the overall personality or relative adjustment of the stutterer, have sought to tap what might be considered more basic personality variables such as level of aspiration (*57, 89, 90*), perseverative tendencies or rigidity (*25, 32, 51, 92*) and self-concept (*34, 95, 106*). Since the focus of the present paper is on the more global aspects of personality and adjustment, it can simply be noted that these results suggest that stutterers do set a somewhat lower level of aspiration than nonstutterers, that stutterers are somewhat more perseverative than nonstutterers, and that stutterers do not have a different self-concept from nonstutterers, at least according to the measures of self-concept used by these investigators. In any event, since these findings are provocative and suggestive rather than well established, considerable additional work will be necessary before the implications of such data for either clinical or research work can be clearly seen.

In summary, the most general conclusion to be drawn from these studies of adult stutterers is that stutterers do not appear to have a particular personality pattern and that when they are compared with severely maladjusted individuals, for example, psychiatric patients, they do not appear very maladjusted. When, on the other hand, they are compared with presumably normal individuals they do appear different, usually somewhat more anxious, tense and socially withdrawn. There appears to be little evidence to support the contention that adult stutterers, any more than child stutterers, are neurotic or severely maladjusted. While there is evidence that adult stutterers do have more problems than adult nonstutterers, it is impossible to conclude from these studies whether these problems were etiological to the development of stuttering or developed as a consequent to the social reaction to the stutterer. This same question is similarly left unanswered by the research in the other pathologies of speech. The important problem of the relationship of personality and therapeutic progress remains relatively unexamined except for three studies using the Rorschach.

*Evaluation of the Studies of Stuttering.* While a large number of investigators have studied the personality and adjustment of stutterers and their parents, due to methodological inadequacies, such as use of unvalidated instruments, small *N*s and failure to cross validate, few trustworthy generalizations were evident. In general there was some evidence to support the conclusion that stutterers' parents, while not maladjusted themselves, did tend to play a role in the

development of stuttering. There tended to be no consistent evidence to indicate that either the child or adult stutterer has a consistent personality pattern which is different from that of nonstutterers. While adult stutterers did appear to have some adjustment difficulties, they were quite different in this respect from severely maladjusted persons; the bulk of the evidence provided little support for those theorists (*24, 96*) who insisted that there is a clear-cut relationship between neuroses or severe maladjustment and stuttering. One quite important consideration in this area—the role of personality, either the stutterer's or the parent's, in therapeutic work with the stutterer—has been relatively ignored by research workers.

## Summary

The purpose of this paper was to survey the literature reporting some empirical relationships between measured personality and the major functional disorders of speech—articulation disorders, delayed speech, voice disorders and stuttering. In each of these four areas, the published literature of the past 25 years was categorized according to parental personality and adjustment and according to personality and adjustment of the speech-disordered individual himself, first as a child and then as an adult. Where appropriate, the methodological and conceptual limitations of the studies were pointed out and suggestions for additional research made. In general, these methodological and conceptual limitations were so important that few, if any, generalizations were clearly suggested by these studies, emphasizing the need for more and better research.

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# Functional Speech Disorders And Personality: Methodological And Theoretical Considerations

Leonard D. Goodstein

In the past twenty-five years there has been a widespread interest in the relationship of personality and the functional speech disorders. When the number and importance of human social contacts mediated by speech are noted, the hypothesis of a high positive relationship between effective speech and effective personality is suggested. This hypothesis has frequently been put to empirical test, especially since the recent development of personality tests has made convenient measuring instruments readily available.

Goodstein, in his critical review of the reported empirical relationships between measured personality and the major functional disorders of speech, concluded that, 'In general, these methodological and conceptual limitations were so important that few, if any, generalizations were clearly suggested by these studies, emphasizing the need for more and better research' (*10*, p. 372). Sheehan, in his review of the projective test research with stutterers (*20*), and Spriestersbach, in his review of some of the research in articulation disorders and personality (*23*), have both come to much the same conclusion. The purpose of the present paper is to discuss certain methodological and theoretical problems involved in personality research with individuals who have speech problems in the hope that such a discussion may be of some value to future investigators.

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## General Methodological Considerations

*Statistical Considerations.* The importance in experimental work of using adequate and proper statistical tests and of understanding statistical inference should not require discussion here. Certainly it is beyond the scope of this paper to discuss extensively statistical techniques, but one recurring statistical deficiency deserves special mention, namely, the failure to base conclusions upon the statistical tests used. Bjermeland (*3*), for example, concluded that her Thematic Apperception Test results indicated that her functional articulatory children were more frustrated and less well adjusted than her matched controls. This conclusion was reached despite the fact that the differences in her obtained scores were small and statistically insignificant. Exploratory research into the areas where little is empirically known, such as the relationships between personality and speech, frequently raises concern about the possibility of statistically rejecting a true hypothesis (Type I error, *13*, pp. 66-72). This concern, however, may be properly avoided by setting a lower level of confidence for

example, 10 or 20%, for the statistical tests rather than by ignoring the results of such tests in drawing conclusions. There is at least one other alternative for the experimenter and that is to decide in advance upon the absolute magnitude of the differences necessary to make these differences *practically* important. Then, taking into account the variability of the measures, set the sample size large enough to maximize the possibility of obtaining such differences at a reliable level of confidence. Large samples, however, have not been frequently used in this kind of research. Goodstein (*10*), for example, has noted that the median *N* in the published research with articulatory disorders was only 36. The smallness of the samples may, in part, account for the seeming reluctance of some investigators to accept their own statistical results.

A somewhat related problem involves the interpretation of a large number of tests of significance in a single study. Shames (*18*), for example, ran 160 chi-square tests in his study relating personality test measures to success in stuttering therapy. He reported 11 of the 160 tests yielded statistically significant results ($p<.10$), but *by chance alone* 16 of these tests should be significant. Extreme caution in the interpretation of such results is necessary and cross-validation clearly required.

In general it would appear that much of the prior research has been invalidated or made difficult to interpret because of inadequate statistical procedures. Extreme care should be exercised in the future to avoid recurrence of such methodological errors.

*Cross-Validation.* Individuals with speech problems are quite heterogeneous, coming from a wide variety of social and economic backgrounds, from different geographical locations and from different age groups. It is unlikely that any given sample used in a single study will adequately represent these diverse groups. The characteristics of the particular sample should be specifically noted in the description of the study and carefully considered in the conclusions. Overgeneralizations, not supported by the obtained data, would then be less likely to occur.

The importance of cross-validation of already reported results, with samples from similar *and* somewhat different populations, cannot be too greatly stressed. A series of such replications in similar groups provides the best check on the reliability of these previous findings as it is unlikely that erroneous results in a given direction would repeatedly reach statistical significance by chance alone. The relevance of this point may be clearly seen in the review by Goodstein (*10*) which cited a number of results later unsubstantiated by replication. Cross-validation, using groups that differ in some respect from the original group, also provides one index of the generality of the conclusions. Extreme caution should usually be exercised in the interpretation of experimental results when cross-validational data are absent.

*The Need for Control Groups.* The control group method for evaluating experimental findings has been rather consistently used in recent personality and speech disorder research, although earlier investigators frequently failed to take such precautions. A more difficult problem concerns the nature of the control group and the comparability of the control

and experimental groups. Johnson (*11*), Spriestersbach (*22*) and Dahlstrom and Craven (*5*) each compared the stutterers' personality test results with those obtained from normal controls and psychiatric patients. These investigators concluded that the stutterers, although they did show some signs of social maladjustment, resembled the normals more than they did the patients. The conclusions of these investigators would, almost certainly, have been different had they made only one of these comparisons. Other investigators have used only normally speaking individuals matched to the speech-handicapped group on the basis of such considerations as age, sex and education, while others have used siblings of the speech handicapped. It should be clear that the results of such investigations must always be interpreted in terms of the control group used and that adjustment and personality are, at least in this sense, relative terms.

Frequently the test norms supplied by the test authors, rather than norms obtained from any carefully matched control group, have been used as a basis of comparison. This is a dangerous procedure as it assumes that the test standardization group constitutes an adequate control sample for the current research and this is not always the case. For example, Darley (*6*), on the Rogers Test of Personality Adjustment, found no significant differences between his stutterers and controls but the scores of both groups would indicate a serious degree of social maladjustment. Darley's selection of his control cases was such that these controls should have been fairly typical, normally-adjusted youngsters and, further, none of his other control data tended to support this finding of maladjustment. This result can be more easily explained in terms of inadequate test norms or changes in the test with time. In any event, the important point is that using the test norms as the only control Darley might have interpreted his stutterers' results quite differently.

It has been frequently noted (*16*, *17*) that speech handicaps, especially stuttering, are more common in males than in females. On the other hand, it also has been frequently noted (*2*, pp. 478-482) that females give more neurotic or maladjusted responses to personality tests than males, probably because of subtle social factors which tend to permit admission of such 'weakness' in females. These two findings would suggest that sex is an important factor to consider in the composition of an adequate control group and that the number of males and females should be equated or proportional in the experimental and control groups.

The necessity for an adequate control group in studies of the effectiveness of therapy should not be overlooked, particularly when personality tests constitute one of the criterion measures. The psychotherapy literature contains a number of examples (*8*, *24*) of significant personality test score changes in the direction of better adjustment for the untreated control group as well as for the treated experimental group. Studies in both speech therapy and psychotherapy must utilize an adequate, untreated control group for an effective evaluation of the results of therapy.

## The Measurement of Personality and Adjustment

The problem of how the personality and adjustment of the speech hand-

icapped are assessed is a crucial one for both research and clinical work. Writers on personality measurement (*1, 9*) essentially agree that the characteristics of a good personality test include validity, reliability, objectivity and adequate standardization. These writers, as well as the Buros collection of test reviews (*4*), have generally indicated that most of the widely used measures of personality fall short of meeting all of these characteristics of a good test, particularly the requirement of validity. Rationally-derived personality inventories, those tests on which the selection and scoring of items have been determined by so-called expert judgment (Bell Adjustment Inventory, Bernreuter Personality Inventory, California Test of Personality), have been widely and severely criticized (*1*, pp. 93-100; *4; 9*, pp. 180-183) as lacking validity. On the other hand, empirically-derived instruments such as the Minnesota Multiphasic Personality Inventory and the New California Personality Inventory, for which the selection and scoring of items have been empirically determined by the use of independently established criterion groups (*14*), have produced more promising results (*1*, pp. 121-124; *4; 9*, pp. 241-243). Validity studies with projective techniques such as the Rorschach and the Thematic Apperception Test have yielded confused and contradictory results suggesting that studies using such tests must be interpreted with caution (*1*, pp. 162-171; *4; 9*, pp. 352-369). It would be an unwarranted assumption, at least at present, to regard these projective tests as generally validated measures of personality, suitable for uncritical use as criterion variables.

The choice of a personality test for experimental use is a crucial decision and the investigator should carefully evaluate his choice as to its appropriateness and acceptability. The criteria of a good test noted above as well as the published evaluations (*4*) should be used in this choice and the limitations of the test should be considered in the conclusions as well as noted in the description of the study.

The investigator in the area of personality and speech also should guard against the possibility of contamination in his study. Many techniques of personality measurement, such as projective tests and interviews, involve the direct observation of the oral behavior of the subject. The individual with speech problems is placed at a particular disadvantage in such a procedure and his difficulties are frequently magnified by the necessity for oral productivity. In any event, these procedures permit the tester or interviewer to identify the speech-handicapped individual as such and this knowledge may tend to maximize experimenter bias, for example, systematic tendencies to judge those who are thus handicapped as less well adjusted than those who are not. Much the same criticism can be made of teachers' and parents' ratings of the adjustment of the child with speech problems (*12*). More reliance can generally be placed upon those studies in which such contamination is not possible.

## Theoretical Considerations

Studies of the relationship between speech handicaps and personality raise the important question of whether the obtained personality differences are the cause of the handicap or its result. As Sanford noted, 'There

is sometimes doubt as to the direction of the influence involved in the relation of adjustment to disorders of speech, but that the relation is there is clear' (*15*, p. 171). Generally in dealing with individuals with a long history of speech disorders where many interactive forces have been operating, it is impossible to distinguish cause and effect.

It may be noted that longitudinal studies could provide some evidence on this point. If it were possible to obtain personality measures prior to the development of a speech problem and then again subsequent to its development, some partial answer to this question would be provided. Unfortunately, speech problems have their origins in childhood before personality can be adequately measured, at least with currently available instruments. In a less clear-cut fashion, the changes in personality following successful speech therapy may shed some light on this problem.

In general, the importance of age as a factor in the relationship between speech disorders and personality has been relatively ignored. Obviously the implications for personality and adjustment of an articulatory problem in a five-year-old are different from those in a young adult. Longitudinal studies, despite their difficulties and limitations, will provide valuable information about the change in personality over time in individuals with speech disorders. The factor of age should provide an important area for future study, both longitudinally and cross-sectionally.

It is obvious that speech disorders, like all other obvious anomolies, have a social stimulus value, and the resultant personality of the handicapped individual is partially formed by the responses of others to the handicap. Between-groups comparisons which demonstrate only that individual with speech problems differ from normal speaking persons yield little information about the operation or relative importance of the social and psychological factors which underlie these differences. While comparisons of the speech-handicapped with adequate controls represents good research methodology, such comparisons seem to contribute little to any theoretical understanding of speech handicaps. That speakers with speech problems and normal speakers are different is immediately obvious and additional studies of these differences should add to an understanding of the theoretical implications of these differences.

Those studies which have attempted to deal with more basic dimensions of personality having some theoretical basis, such as level of aspiration (*21*), would appear more fruitful at this stage of knowledge than those studies which simply show differences between easily distinguishable groups. Of potentially great usefulness are those studies which have utilized within-groups comparisons on the basis of such considerations as the level of severity (*5*) and the type of speech problem (7) and, more importantly, the individual's responsiveness to remedial treatment (*19*). Since there are more candidates for speech therapy than therapists to treat them, some selection of good treatment risks would appear to be a most desirable development. Since the results of treatability studies are only suggestive and provocative, much additional work is required before the findings should be applied in the clinic. Certainly research directed at such problems is more likely to pay dividends

than most of the previously reported studies.

## Summary

Systematic reviews of the empirical relationships between speech disorders and personality have been critical of the methodological inadequacies and theoretical limitations of research in this area. The present paper has surveyed some of these inadequacies and limitations, including statistical considerations, the requirements of sample size, the necessity for control groups and the problem of cross-validation. The problems involved in personality assessment were discussed and some suggestions for future research, especially within-group comparisons and longitudinal measurement, were made.

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# Articulation And Nasality In Cleft Palate Speakers

Rolland J. Van Hattum

Individuals with clefts of the palate typically present two basic speech problems—defective articulation and poor voice quality. The present study is an outgrowth of the clinical observation, supported by some research, that listener judgments of hypernasality in cleft palate speakers are influenced by the speakers' misarticulation.

In an unpublished study conducted at the Pennsylvania State University in 1953, McDonald and Van Hattum had 10 judges listen to a recorded sample of a standard passage read by five speakers and then rate degree of nasality on a five-point scale (*zero* representing the absence of nasality and *four* representing extreme nasality). Four of the five speakers were cleft palate subjects whom the investigators considered to have nasal voice quality because isolated vowels phonated by them were judged to be hypernasal. The fifth speaker, unknown to the judges, presented a severe articulation problem with no oral pathology; the investigators did not consider the voice of this speaker to have an abnormal degree of nasality on the basis of their judgments of the production of isolated vowels. The judges, all of whom were graduate students experienced in listening to voice quality and to cleft palate speech, without exception rated the articulatory-defective subject as being more nasal than the cleft palate subjects.

The purpose of the present study was to test the hypothesis that there is a relationship between judgments of articulatory ability and judgments of nasality in the speech of cleft palate subjects. In other words it was hypothesized that, given two cleft palate subjects with similar anatomical defects and similar degrees of nasality on their isolated vowels, the subject with the better articulation would be likely to be judged as having less nasality than the subject with poorer articulation.

## Procedure

Materials were prepared for testing (a) articulation in connected speech, (b) nasality in connected speech, (c) articulation of consonants in syllables and (d) nasality of isolated vowels.

To obtain the measures of articula-

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tion and nasality in connected speech, 10 sentences, each short enough to be spoken on a single breath, were constructed from familiar words. The sentences included the various phonemes in approximately the same proportion in which they are reported to occur in American English by Dewey (*1*) and Voelker (*2*).

The consonants in the 10 sentences were classified with regard to position as initial, medial and final. Because of lack of agreement on the part of authorities in the field, it was arbitrarily decided to consider consonants occurring at the beginning of a sentence as initial, consonants occurring at the end of the sentence as final and all other consonants as medial.

The material to be used for obtaining a measure of the articulation of consonants in syllables (syllable articulation) consisted of combinations of the consonants with the vowel [ɑ] in order to give each consonant a controlled environment. The three positions were maintained in the measure of syllable articulation. If [d], for example, occurred in the initial position in one of the sentences, it was produced in the syllable [dɑ] in the measure of syllable articulation; if in the medial position, it was produced as [ɑdɑ] ; and if in the final position, it was produced as [ɑd]. Each consonant was produced as frequently as it occurred in the sentences.

Each vowel or diphthong was phonated in isolation as frequently as it occurred in the sentences. In order to simplify terminology, the expression 'isolated vowels' will be used to include both vowels and diphthongs produced in isolation.

Each subject produced 10 sentences, 51 vowels and 73 consonants. Twenty subjects (11 males and nine females) recorded these materials at their habitual pitch levels. Special instrumentation was employed for the purpose of holding intensity and duration constant. All subjects had clefts of the palate; 13 of them also had lip involvement. Eight had surgically repaired palates while the palates of 12 were prosthetically restored. The subjects ranged in age from 12 to 35 years with a mean age of 20 years. The amount of prior individual speech therapy ranged from none for two subjects to 240 hours for one subject. All were within the normal range of intelligence and none had a hearing problem which was judged to contribute to the voice quality or articulatory problems.

Three listeners were selected from a group of nine graduate students in clinical speech. The recordings for 10 subjects were selected at random and were presented twice to the nine students. The three whose ratings of nasality and judgments of accuracy of consonant production were most reliable, according to agreement with self and with the group, were selected to do the final rating and judging. They heard the recorded speech samples, as produced by the 20 subjects, as often as they wished in order to complete the experimental task. Nasality of the vowels and in the sentences was rated on a seven-point scale, *zero* representing the absence of nasality and *six* representing extreme nasality. The listeners also judged the accuracy of production of consonants in syllables and in sentences, indicating whether each sound was produced correctly or incorrectly.

TABLE 1. Correlation coefficients estimating relationships among several measures of speech for 20 cleft palate subjects.

| | *Sentence Nasality* | *Syllable Articulation* | *Nasality on Vowels* |
|---|---|---|---|
| Sentence Articulation | −.64* | .75* | .07 |
| Sentence Nasality | | −.67* | .48† |
| Syllable Articulation | | | .01 |

*Significant at 1% level
†Significant at 5% level

The first 20 sentences were repeated at the end of the judging session so that the reliability of the judges could be determined. With regard to judgment-rejudgment of nasality, a coefficient of correlation of .91 was obtained; for the two sets of articulation scores, a coefficient of correlation of .84 was obtained.

## Results

For each of twenty subjects there were four measures: (a) sentence nasality, (b) nasality on vowels, (c) sentence articulation and (d) syllable articulation. Each measure was the average for the three listeners. Each of the four measures was compared with each of the other three measures by means of Pearson's correlation procedure. A negative correlation between measures of nasality and of articulation indicates a relationship between severity of nasality and accuracy of articulation. Table 1 presents the obtained coefficients.

The measures of accuracy of articulation in syllables and in sentences were significantly related, as indicated by the obtained $r$ of .75. The common variance between the two sets of measures, however, is only 56% ($r^2 = .56$). For the subjects in this study considerable error would thus be introduced if articulatory ability in connected speech were to be predicted by the results of testing sounds in syllables or single words.

The ratings of nasality on isolated vowels and ratings of nasality in the sentences containing these vowels were also significantly related. The magnitude of the obtained $r$ of .48 would, however, definitely contraindicate predicting one measure from the other for clinical purposes. For research purposes, also, it is quite evident that one of these measures cannot be substituted for the other.

The severity of nasality in sentences and the accuracy of articulation in sentences, as judged by the listeners, were significantly related, the obtained correlation coefficient being −.64. A similar relationship, as indicated by a correlation coefficient of −.67, was found between measures of accuracy of articulation in syllables and measures of nasality in sentences.

Any relationship between either of the two sets of measures of accuracy of consonant production and

the set of measures of severity of nasality on isolated vowels was apparently a chance relationship. The obtained coefficients were .07 and .01. These results thus provide no evidence that there is any relationship between ratings of severity of nasality and judgments of accuracy of consonant articulation when the effect of one upon the other is minimized. It was not possible to present to the judges examples of consonant articulation without combining the consonants with vowels; combining the consonants in the standard way with the vowel [ɑ], however, apparently did not result in any effect from nasality in the vowel upon judgments of accuracy of consonant articulation.

Measures of individual subject performances on the four speech measures were evaluated in terms of the hypothesis which states in effect that two subjects with similar degrees of nasality on isolated vowels are likely to differ in the degree of nasality perceived in their connected speech if their articulatory ability differs. To provide for making the comparisons, each subject's scores on the four measures were converted to standard scores.

Seven subjects judged to have good articulation were judged to have less nasality in the sentences than on the isolated vowels; nine subjects judged to have poorer articulation were judged to have more nasality in the sentences than on the isolated vowels. On the other hand, two subjects judged to have poorer articulation were judged to have less nasality in the sentences than on the isolated vowels; the two remaining subjects gave indeterminate performances which were analyzed and similarly interpreted as leading to rejection of the hypothesis. Thus the data for 16 of the subjects provided evidence to support the hypothesis. It seems especially significant that none of the subjects judged to have better articulation was judged to have more nasality in the sentences than on the vowels.

## Summary

The purpose of this study was to test the hypothesis that there is a relationship between judgments of articulatory ability and judgments of degree of nasality in the speech of cleft palate subjects.

Ten sentences were constructed which contained phonetic elements in approximately the same proportion in which they are reported to occur in American English. The vowels and consonants were tabulated to determine their frequency of occurrence and, in the case of the consonants, their position (initial, medial or final). Their frequencies and positions were maintained in isolated productions of the vowels and productions of the consonants in syllables in combination with the vowel [ɑ].

Twenty subjects with repaired or prosthetically restored clefts of the palate recorded the sentences, vowels and syllables which were judged by three listeners both for accuracy of production of the consonants in the sentences and in the syllables and for the degree of nasality on the isolated vowels and in the sentences. Coefficients of correlation were computed to estimate the relationships among the measures.

The following conclusions with respect to cleft palate speech seem warranted: (a) Judgments of accu-

racy of articulation and degree of nasality appear to be independent when the influence of articulation and nasality on each other is minimized. (b) Judgments of degree of nasality in connected speech tend to vary with judgments of nasality on isolated vowels. The relationship is not strong enough for one measure to be useful in predicting the other. (c) Judgments of degree of nasality tend to vary with judgments of the accuracy of articulation, judgments of superiority of articulation tending to be associated with judgments of less nasality.

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